ELECTRICITY CONSERVATION
Supply Curves for Ontario

Prepared for the
Ontario Ministry of Energy
By

Marbek Resource Consultants

Ontario Ministry of Energy

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Minister

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ELECTRICITY CONSERVATION SUPPLY CURVES FOR ONTARIO

Final Report

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ELECTRICITY CONSERVATION SUPPLY CURVES FOR ONTARIO

1. INTRODUCTION

Improving the productivity of electricity use can displace electricity supply in the provision of electricity services. The cost of electricity supply is usually expressed in cents per kilowatt-hour, and the basis of the electricity conservation supply curve is the calculation of the costs of various conservation measures (more precisely, electricity productivity improvements) in units of cents per kilowatt-hour saved. This allows the direct and symmetrical comparison of supply and demand options for the provision of electricity services.

This report describes the method, data, assumptions and calculations used to produce a set of preliminary electricity conservation supply curves for Ontario. The preliminary nature of these curves should be emphasized; the technique for producing such curves is still under development, especially for the macro supply curves developed here. The object of the exercise was to produce four electricity conservation supply curves for Ontario -- one each for the residential, commercial and industrial sectors, and one curve that combined the sectoral curves.

The next section of this report introduces the concept of the conservation supply curve, the different types of curves, and general methodological issues and problems. Section 3 describes the specific method used in this study. The curves themselves, along with brief explanations, are presented in Section 4. The final section of the body of the report describes some of the lessons learned in this innovative exercise and suggests some possible directions for future work. Above all, it must be emphasized that comparison of conservation supply curves with conventional economic supply curves is not straightforward.

Details of the calculations are presented in the Appendix, and the various data sources referred to throughout are listed in the Bibliography.

2. CONSERVATION SUPPLY CURVES

The concept of the conservation supply curve derives from an end-use orientation to the analysis of fuel and electricity supply and demand. The starting point of this approach is the recognition that demands for fuels and electricity are derived from more fundamental demands for energy services. To identify the most cost-effective way of providing the energy end-use services in an economy, techniques and technologies that can reduce the fuel or electricity required for a particular end-use service must be compared on a symmetrical basis with fuel and electricity supply options. The "conservation supply curve" is a conceptual tool for making such symmetrical comparisons. It is partly analogous to the conventional economic supply curve.

The notion of a supply curve comes from economic theory. It expresses the instantaneous relationship between the price of a given commodity and the amount of the commodity that will be delivered at each price. Even in theory, it is a relatively sophisticated concept (for example, what is the "commodity" and to what point is it delivered).

Despite these theoretical and practical difficulties, the concept of a supply curve is so useful that, under rather less restrictive assumptions, it became common in the 1960's to extend the idea to relationships between price (or cost) and sets of opportunities to produce minerals and energy. Still later, the importance of conservation became clearer in the sense of an alternative way to deliver a specific end-use service. There turned out to be little difference between producing an added unit of some commodity and adjusting the end-use technology in such a way that that unit was no longer necessary. The term "supply price" came to be used equally for additions to energy supply and options for energy conservation supply curves that are the subject of this analysis.

There are three types of information required to construct any conservation supply curve -- the baseline energy use (against which the savings are measured), the energy savings that can be achieved by a particular measure, and the cost of the measure.

Baseline Energy Use

Because the conservation "supply" is actually the difference between the energy use if the measure were not implemented and the energy use after the measure is implemented, it is very important to have accurate baseline energy end use data. This presents a particular problem in the construction of

conservation supply curves for future years, since any baseline will of necessity be arbitrary.

Energy Savings

Equally important as the accuracy of the baseline data is an accurate calculation of the amount of energy that will be saved by the implementation of a particular measure. This knowledge is usually based on experience and on mathematical models (for example, building energy models). Models are especially important if several measures are being considered on one curve, because the baseline energy use will change after each measure, and this in turn will affect the savings that can be achieved with subsequent measures.

Cost of Measures

The conservation supply curve is most versatile when the costs of the conserved energy can be presented as independent of the costs of supply. This implies a rejection of such indicators as payback, internal rate of return, net present value and benefit/cost ratios, as they all require some assumption about future energy prices. Two indicators are considered here, one related to payback calculations and the other to life cycle costing.

The unit cost of the conservation energy can be calculated simply by spreading the costs over the savings achieved in the first "n" years. The selection of "n" will depend on the purposes for which the curve is being produced. An individual looking for a payback of three years or less would choose n=3 to calculate the unit cost of the conserved energy. The physical lifetime of the measure could also be used to determine a lower limit of the unit cost using this method.

A more sophisticated method, and one better suited to policy analysis, is to calculate the life cycle cost of the measure, or the cost of conserved energy (CCE) [Meier, 1982]. This calculation divides the discounted value of the initial investment (plus annual O&M charges where applicable) by the annual energy savings. The formula is simply:

$$CCE = (I/E)\ (d/(1+d)^{-n})$$

where I is the initial investment
E is the annual saving in energy (compared to baseline)
d is the discount rate
n is the life time of the measure (in years)

The equation illustrates the relative importance of various of the input data, including the energy savings (E), the cost of the measure (I), the discount rate (d) and the lifetime (n). The elasticities of the CCE are as follows [Meier, 1982]:

With respect to investment I: +1

With respect to energy savings E: -1

With respect to amortization time n: $(n \ln(1+d))/(1-(1+d)^{-n})$

With respect to discount rate d: $1 + ([nd]/[(1+d)^{n+1}-(1+d)])$

The CCE is particularly sensitive to the choice of discount rate, especially in the 1 to 5% range typically chosen for constant dollar discount rates.

Interactive Effects

As mentioned above, the baseline against which energy savings are measured is affected by all other measures previously implemented, and this is the root of the interactive effects which constitute the most difficult methodological problem in the construction of conservation supply curves. Measures typically save some percentage of the baseline energy use, and so the absolute savings they achieve change (usually downward) in proportion to the amount of energy saved by all the previous measures. This in turn affects the unit cost of the measure (which is inversely proportional to the absolute value of E).

An example is provided by Meier [1982], who developed an algorithm for calculating the CCE for a sequence of space heating conservation measures for a house. First, the CCE of each of the eight measures is calculated as if it were the first to be implemented. Then the lowest cost measure (duct insulation in this case) is implemented, the baseline energy is recalculated and the unit costs of the remaining measures are recalculated and re-ordered. The iteration continues until the optimum order is identified. However, if the initial cost of the duct insulation is increased until it is slightly more expensive than the next cheapest measure (wall insulation), its ultimate position in the order falls not to second but to fourth because of the interactive effects on other measures of insulating the walls first.

Commercial lighting conservation measures provide another example of these interactive effects. Reductions in the energy output of lights reduce the cooling requirements in commercial buildings in the summer and increase the heating

requirements in the winter. Thus, lighting efficiency improvements also save air conditioning energy but, if implemented first, increase the unit costs of air conditioning efficiency improvements, and conversely for heating energy.

These interactive effects illustrate another important limitation of conservation supply curves that are based on the cost of the conserved energy. The implementation of one measure can send the unit cost of a similar measure skyrocketing. For example, measured against a common baseline, insulating an attic to level A may save electricity at 2¢/kW.h, and insulating it to level B may save more electricity at a slightly higher unit cost. But because of the high labour component of this measure, if the attic is insulated to level A, the unit cost of insulating to level B, given the new baseline, will increase greatly. Thus to avoid double counting, a unit cost value must be selected to provide a basis for choosing between similar and mutually exclusive (for practical purposes) options. A supply curve of electricity conservation available up to, say, five cents per kilowatt-hour will be quite different from one that goes up to three cents per kilowatt-hour, even in the low cost range.

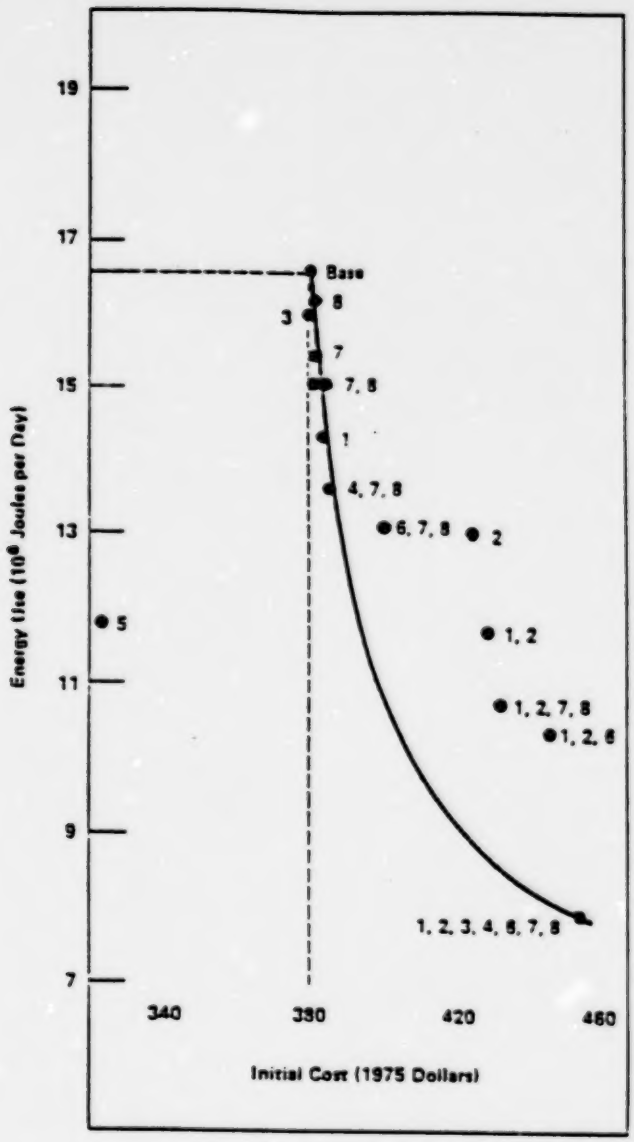
Micro Conservation Supply Curves

The simplest and most well-defined conservation supply curve is that for a single unit end-use device or process. For example, Figure 1 is a supply curve designed to show collections of technical changes that could save electricity in a large, modern refrigerator, and how their costs compared with the resulting savings. It is also a relatively simple task to construct a conservation supply curve for a single building or industrial plant. For example, Figure 2 shows a gas conservation supply curve for a particular single-family dwelling. At this micro level, conservation supply curves can be determined with great accuracy and are the stock-in--trade of the energy services industry in recommending conservation investment schedules for their clients. The precision of these micro supply curves is a direct result of the precision of the data that is possible at this level and of the detailed knowledge of the individual building or end use device that can be brought to bear.

Macro Conservation Supply Curves

A "macro conservation supply curve" describes the total conservation potential for many units, and "multiple end-use, macro conservation supply curves", aggregated for an entire sector of the economy are the most complex of all. The

complexity derives from the large variations in the energy use, costs and effects of particular measures from one application to the next. The analyst must rely on average base line energy use, average costs for measures, average effects of the measures, and, most difficult, average interactive effects. As Meier points out, "a kind of uncertainty principle applies here. The more precisely one specifies a conservation measure (to more accurately know its energy savings), the less precisely one knows the stock to which the measure applies". Until much larger statistical energy end-use and conservation data bases are available (that would allow application of techniques such as Monte Carlo to the aggregation problem), the development of macro conservation supply curves will require the heroic assumption that distributions are normal about the averages, and that the data allow one to make a reasonable approximation of the average.



KEY

1 Increase insulation thickness
2 Improve insulation thermal conductivity
3 Remove fan from cooled area
4 Add anti-sweat heater switch
5 Eliminate frost-free and forced air systems
6 Improve compressor efficiency
7 Increase condenser surface area
8 Increase evaporator surface area

*Refrigerator is 16 cu ft and incorporates the options shown in the key.

FIGURE ONE

DAILY ENERGY USE (OR INTENSITY) COMPARED TO THE INITIAL COST OF A TYPICAL TOP-FREEZER REFRIGERATOR*

Source: Hoskins and Hirst, Oak Ridge National Lab Report CON-6 (1977).

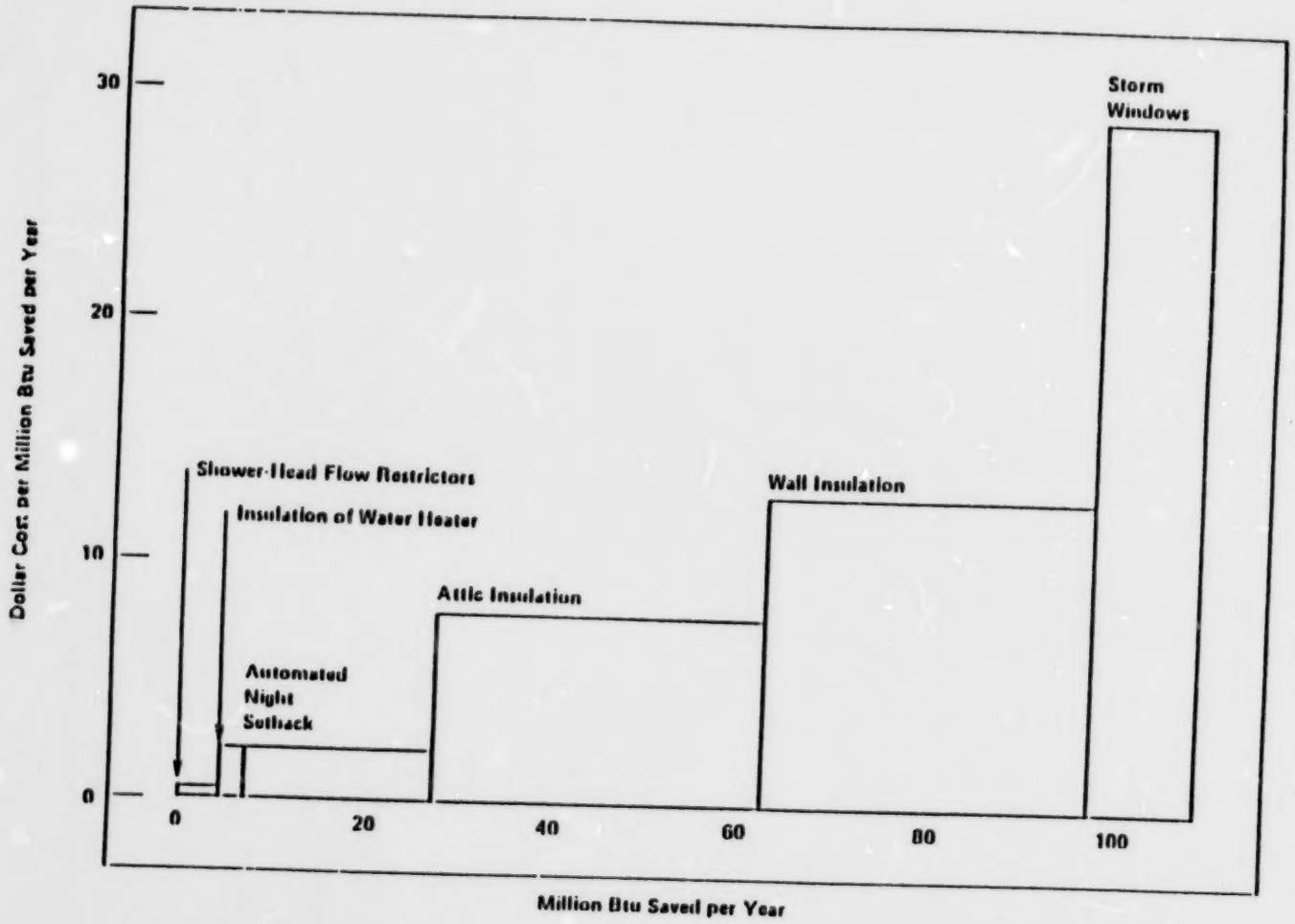


FIGURE TWO

SAVINGS FROM HOT WATER CONSERVATION

In Terms of Gas Conserved in a 1,400-sq ft Uninsulated Single-Family Dwelling

Source: Rosenfeld, Lawrence Berkeley Lab Report 5926 (1977).

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3. APPROACH AND METHOD FOR THIS STUDY

The objective of this study was to create multi-end-use macro supply curves (sometimes called "grand supply curves") for electricity conservation for residential, commercial and industrial sectors in Ontario, as well as a composite curve showing the combined conservation potential in all three sectors.

Given the complexity and enormity of the task, a number of simplifying constraints were agreed to at the outset and at a workshop on the method held during the course of the analysis.

First, the analysis is performed for the conservation of electrical energy, and not for peak capacity. Second, the analysis focuses on the maximum physical conservation potential. No judgements or analysis are presented on rates of penetration, or on the effect of factors other than technical potential that might limit application. Neither is there any analysis of the conservation potential beyond the base year, which was selected to be 1985.

Regarding data sources, the analysis relied on existing end use energy data, engineering and cost studies of conservation potential. Even so, a great deal of recalculation of costs and energy savings was required.

One implication of these constraints is that the calculations are representative, but not comprehensive. A selection of measures were analyzed, but there are almost certainly others which are cheaper and/or would yield greater savings that are not included here. In particular, there is certainly a large remaining potential for "low cost/no cost" conservation in the base year electricity use, but we have not included these measures because it is impossible (given the energy data base) to know how much has already been implemented. For all these reasons, the curves are <u>preliminary</u>.

For the cost calculations, the formula described above for the discounted unit cost was applied. As agreed at a methods workshop held early during the course of the study, a uniform discount rate of 4% was used to allow comparison with electricity supply cost calculations that are performed using this rate. Amortization periods were set according to the expected lifetimes of each technology.

In the case of similar but effectively mutually exclusive measures, a cost of $0.05/kW.h was used as a reference point. Alternative measures were generally selected on the basis of

which could supply the most conservation at a cost below the reference point.

For each sector, the starting point was 1985 electricity consumption, disaggregated by sub-sector and by end use. Electricity conservation measures and technologies were then identified and their potential to reduce the electricity use in each cell of the sector's end use by sub-sector matrix were analyzed. Unit costs of the saved energy were calculated using the formula for the cost of conserved energy described above. The results were then aggregated across sub-sectors by technology/measure to allow a sector wide assessment of the electricity conservation achievable at different cost levels.

4. ELECTRICITY CONSERVATION SUPPLY CURVES FOR ONTARIO

4.1 Commercial Sector

The analysis for this sector was more detailed than for the other sectors. The details of the calculations for the Commercial Sector Supply Curve are described in Appendix A. Listed in order of increasing unit cost, the 105 commercial sector conservation blocks calculated in Appendix A are as follows:

Block	Unit Cost (¢/kW.h)	Measure	Building Type	Saving (GW.h)
C036	0.77	Fl. Lights -1	Food retail	177.0
C066	0.77	Fl. Lights -1	Hotels	15.0
C022	0.78	Fl. Lights -1	Small retail	171.0
C029	0.78	Fl. Lights -1	Large retail	563.0
C014	0.80	Fl. Lights -1	Large Office	690.5
C082	0.89	Fl. Lights -1	Hospitals	166.0
C074	0.90	Fl. Lights -1	Restaurants	97.0
C097	0.90	fL. Lights -1	Recreation	20.0
C058	1.17	Fl. Lights -1	Coll/Univ	158.0
C002	1.17	Fl. Lights -1	Small Office	55.9
C071	0.58	E/E Motors	Hotel	20.0
C019	0.61	E/E Motors	Large Office	83.6
C026	0.62	E/E Motors	Small retail	10.5
C040	0.63	E/E Motors	Food retail	3.0
C033	0.63	E/E Motors	Large retail	37.0
C087	0.71	E/E Motors	Hospitals	14.0
C010	0.79	E/E Motors	Small Office	55.9
C056	1.12	E/E Motors	Sec. Schools	6.5
C049	1.13	E/E Motors	El. Schools	12.5
C018	1.27	Motors Balance	Large Office	322.0
C032	1.28	Motors Balance	Large Retail	203.0
C039	1.28	Motors Balance	Food Retail	63.7
C086	1.34	Motors Balance	Hospitals	100.0
C070	1.39	Motors Balance	Hotels	56.0
C015	1.40	Fl. Lights -2	Large Office	690.5
C034	1.51	Motors scheduling	Large Retail	154.0
C041	1.51	Motors scheduling	Food Retail	11.6
C013	1.51	Window Glazing	Sm. Off Elect.	152.0
C051	1.55	Fl. Lights -1	Sec. Schools	61.3
C090	1.55	Fl. Lights -1	Warehouse	145.0
C093	1.60	Motors Balance	Warehouse	151.0
C088	1.63	Motors scheduling	Hospitals	39.6
C001	1.64	Fl. Lights -1	Sm. off. elec.	88.3
C044	1.73	Fl. Lights -1	El. schools	103.0

COMMERCIAL SECTOR ELECTRICITY CONSERVATION MEASURES
(continued)

Block	Unit Cost (¢/kW.h)	Measure	Building Type	Saving (GW.h)
C081	1.80	Cooling Equip	Restaurants	33.0
C073	1.80	Cooling Equip	Hotels	19.0
C096	1.80	Cooling Equip	Warehouse	21.0
C020	1.90	Motors scheduling	Large Office	139.4
C063	1.90	E/E Motors	Coll/Univ	9.0
C079	1.90	E/E Motors	Restaurants	7.0
C094	1.90	E/E Motors	Warehouse	29.0
C104	2.00	Water Heating	All types	161.6
C100	2.00	Motors - all meas	Recreation	145.0
C102	2.00	Motors - all meas	Other	160.0
C103	2.00	Cooling Equip	Other	35.0
C089	2.30	Cooling Equip.	Hospitals	19.0
C105	2.50	Space heat -gen.	All types	430.0
C012	2.52	Cooling Equip	Small Office	22.0
C062	2.53	Motors Balance	Coll/Univ	45.3
C078	2.53	Motors Balance	Restaurants	39.0
C055	2.53	Motors Balance	Sec. Schools	34.0
C043	2.56	Cooling Equip	Food Retail	11.0
C035	2.56	Cooling Equip	Large Retail	34.0
C067	2.57	Fl. Lights -2	Hotels	15.0
C008	2.64	Compact Fluor.	Small Offices	22.0
C017	2.65	Compact Fluor.	Large Offices	56.0
C065	2.65	Cooling Equip	Coll/Univ	9.0
C028	2.65	Cooling Equip	Small retail	8.3
C037	2.68	Fl. Lights -2	Food Retail	177.0
C030	2.68	Fl. Lights -2	Large Retail	563.0
C023	2.70	Fl. Lights -2	Small Retail	171.0
C021	2.82	Cooling Equip	Large Office	36.0
C080	2.85	Motors scheduling	Restaurants	17.0
C057	2.85	Motors scheduling	Sec. Schools	14.6
C064	2.85	Motors scheduling	Coll/univ	19.0
C095	2.90	Motors scheduling	Warehouse	65.0
C009	3.00	Motors Balancing	Small Office	148.0
C011	3.06	Motors scheduling	Small Office	228.0
C072	3.08	Motors scheduling	Hotels	89.0
C075	3.10	Fl. Lights -2	Restaurants	97.0
C098	3.20	Fl. Lights -2	Recreation	20.0
C025	3.29	Motors balancing	Small Retail	34.9
C042	3.00	Refrigeration	Food Retail	294.0
C047	3.00	Compact Fluor.	Elem. School	8.2
C085	3.00	Compact Fluor.	Hospitals	12.0
C054	3.00	Compact Fluor.	Sec. schools	5.0

COMMERCIAL SECTOR ELECTRICITY CONSERVATION MEASURES
(continued)

Block	Unit Cost (¢/kW.h)	Measure	Building Type	Saving (GW.h)
C061	3.00	Compact Fluor.	Coll/univ	11.4
C069	3.00	Compact Fluor.	Hotels	129.0
C077	3.00	Compact Fluor	Restaurants	290.0
C007	3.70	Compact Fluor.	Sm elect. off.	6.6
C016	3.49	Fl. Lights -3	Large Office	966.9
C059	3.63	Fl. Lights -2	Coll/univ	158.0
C048	3.70	Motors balancing	Elem. Schools	62.3
C004	4.00	Fl. Lights -2	Small Office	293.9
C083	4.27	Fl. Lights -2	Hospitals	166.0
C101	4.53	Lights -all meas	Other	250.0
C050	4.87	Motors scheduling	Elem. Schools	26.2
C052	5.30	Fl. Lights -2	Sec. Schools	61.3
C091	5.30	Fl. Lights -2	Warehouse	145.0
C045	5.41	Fl. Lights -2	Elem. Schools	103.0
C003	5.60	Fl. Lights -2	Sm. elect. off	88.3
C099	5.76	Fl. Lights -3	Recreation	20.0
C027	5.90	Motor Scheduling	Small retail	48.8
C031	6.02	Fl. Lights -3	large retail	450.9
C038	6.02	Fl. Lights -3	Food retail	141.4
C068	6.02	Fl. Lights -3	Hotels	12.0
C006	6.60	Fl. Lights -3	Small Office	355.3
C060	7.19	Fl. Lights -3	Coll/univ	158.0
C024	7.78	Fl. Lights -3	Small Retail	119.2
C084	8.22	Fl. Lights-3	Hospitals	166.0
C076	8.90	Fl. Lights -3	Restaurants	77.0
C005	9.30	Fl. Lights -3	Sm elect off	117.5
C053	9.60	Fl. Lights -3	Sec. Schools	61.3
C092	9.60	Fl. Lights -3	Warehouse	145.0
C046	10.50	Fl. Lights -3	Elem. Schools	145.0

The conservation supply curve for the commercial sector presented in Fig. 4.1 shows fifteen blocks of conservation potential, corresponding to the different measures that were considered. The width of each block is the total savings potential from the measure, and the height reflects the weighted average unit cost of applying the measure to the different building types. In order of increasing weighted average unit cost, then, the blocks presented in Fig. 4.4 are as follows:

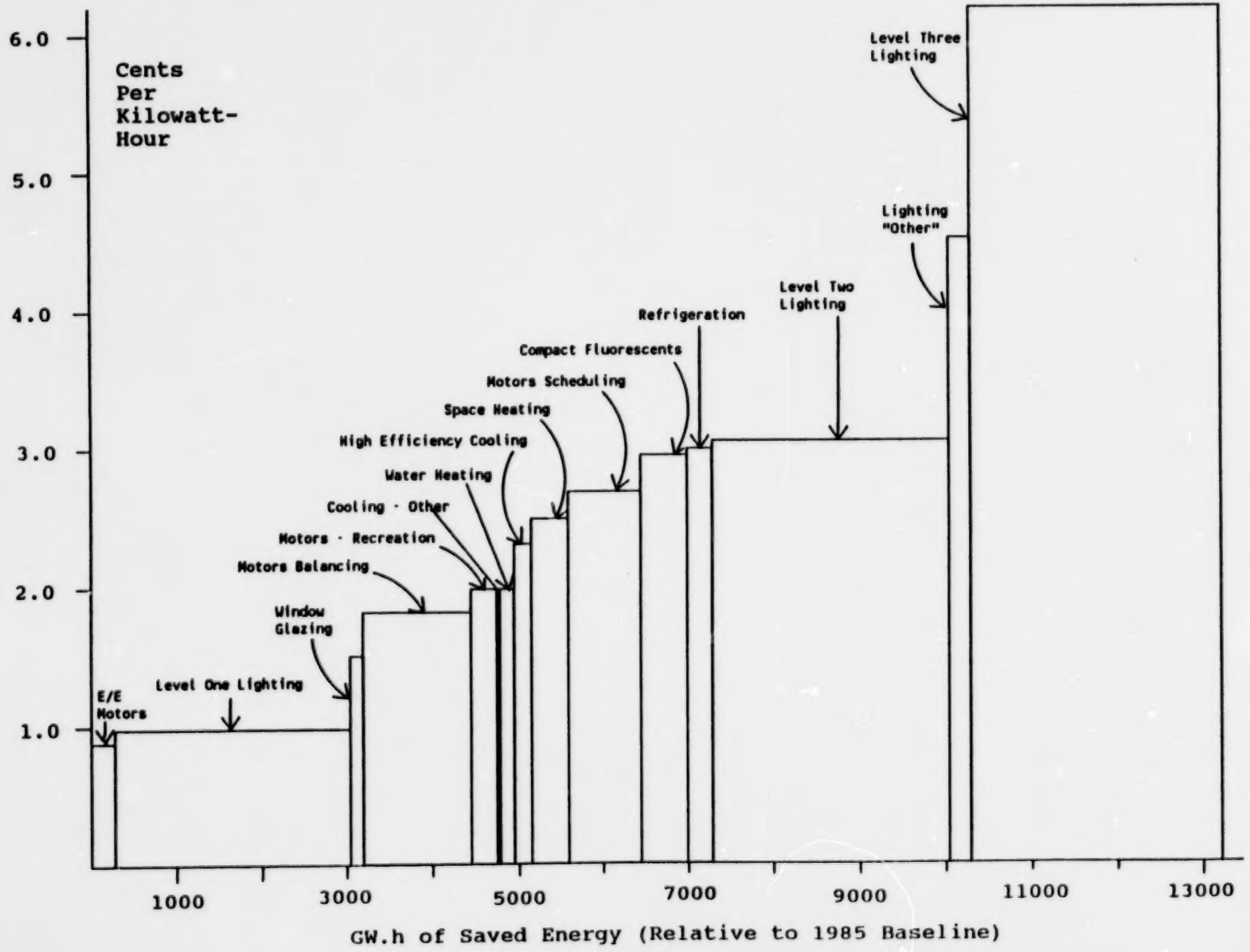
COMMERCIAL SECTOR CONSERVATION SUPPLY CURVE COMPONENTS

Block	Weighted Unit Cost (¢/kW.h)	Measure	Saving (GW.h)
CC1	0.89	Energy Eff. Motors	288
CC2	0.98	Lighting -- Level 1	2749
CC3	1.51	Window Glazing	152
CC4	1.82	Motors -- Balancing	1259
CC5	2.00	Motors -- Recreation	305
CC6	2.00	Cooling -- Other	35
CC7	2.00	Water Heating	162
CC8	2.32	High Eff. Cooling	212
CC9	2.50	Space Heating	430
CC10	2.70	Motors -- Scheduling	852
CC11	2.96	Compact Fluorescents	540
CC12	3.00	Refrigeration	294
CC13	3.06	Lighting -- Level 2	2749
CC14	4.53	Lighting -- Other	250
CC15	6.19	Lighting -- Level 3	2935

By consolidating the detailed calculations in this way, some information is lost. For example, Level 3 lighting measures have a unit cost of only 3.49 ¢/kW.h when applied in large office buildings, but the weighted average unit cost for this measure appears above as 6.19¢/kW.h, reflecting the high cost of this measure in other types of buildings.

FIGURE 4.1

ELECTRICITY CONSERVATION SUPPLY CURVE FOR ONTARIO COMMERICAL SECTOR



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4.2 Industrial Sector

Analysis of electrical energy conservation potential in the industrial sector is probably less limited by conceptual problems than other sectors: interactions among end-uses are more limited, and the end-uses themselves are more clearly defined. However, as if in compensation, the analysis is more heavily constrained by both data problems and outright disagreements over potential than with any other sector.

The data problem is of long standing. More than with other end-users, industrial plants differ even within three and four digit SIC categories sufficiently to make generalizations dangerous. Moreover, while it may be conceptually clear how energy is used, actual measurements of energy use within a plant or for a typical process are not common, or, if undertaken, are not published. For example, no up-to-date listing of electricity use by motors classified by size of motor (and by industrial subsector) could be found for this project. A literature review of industrial conservation studies around the world found very few that provided any indication of cost per unit of energy saved or even capital cost of conservation measures [Figueiredo 1982]. And, even when published, there is no standard approach to presentation of data, units, relationships between power and energy, etc. Over time, data problems for the industrial sector are likely to be resolved, but there is no apparent resolution of the difficulty of using this data in a way that will permit one to make generalizations for the sector.

The other problem is more intriguing and may be less tractable. The range of views about potential energy savings under specified conditions is fairly limited for other sectors; disagreements about likelihood and attainability may be wide, but those about the size of the potential given certain cost ranges and other factors are moderate. Not so with the industrial sector. Here, one source may indicate that between one- and two-fifths of the electrical energy used in a pulp and paper mill could be saved by measures averaging less than $600 per delivered kilowatt; another may indicate that total savings could be no more than a few percentage points for paybacks ranging from three to six years.

The disagreement is most serious with respect to motors, which is unfortunately the biggest term by far in industrial electricity use. Perhaps most prominent in arguing the position for large potential savings is Amory Lovins [1985] who argues that motor and drive train efficiencies are significantly lower than commonly supposed. He claims that total drive efficiency (output at task divided by electrical

input) can be doubled by more efficient motors together with proper sizing, coupling and controlling. This is a much greater improvement than is considered reasonable by other analysts.

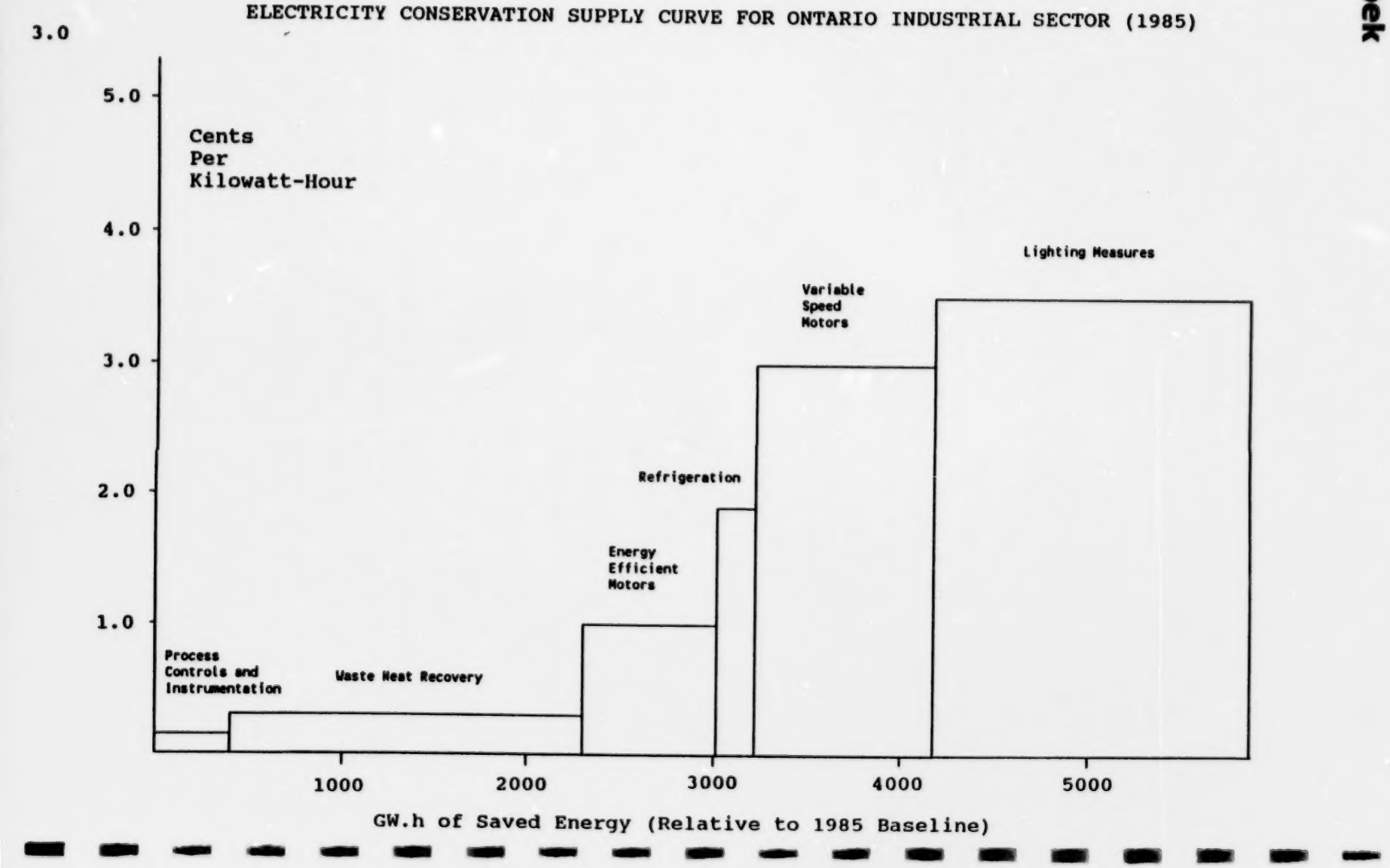
For the purposes of this report, a wide variety of sources was used, and it cannot be assumed that all operated from a common base or adopted equivalent assumptions. There are also variations in the base year of those reports, in the year to which dollars were normalized,etc. For the most part, such variations were ignored as they were assumed to be well within the margin of error itself. The analysis focuses on manufacturing. Mining appears to have enough special characteristics as to preclude generalization from manufacturing [Ontario Hydro 1986c], and the use of electricity in agriculture and construction is relatively small.

The details of the calculations are contained in Appendix B. Listed in increasing order of unit cost, the conservation blocks from Appendix B are as follows:

Block	Measure	Unit Cost (¢/kW.h)	Savings (GW.h)
I2	Process Controls and Instrumentation	0.15	400
I1	Waste Heat Recovery	0.30	1900
I5	Energy Eff. Motors	1.0	715
I4	Refrigeration	1.9	200
I6	Variable Speed Motors	3.0	960
I3	Lighting	3.5	1700

These blocks are shown on a conservation supply curve for the industrial sector in Figure 4.2.

FIGURE 4.2



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4.3 Residential Sector

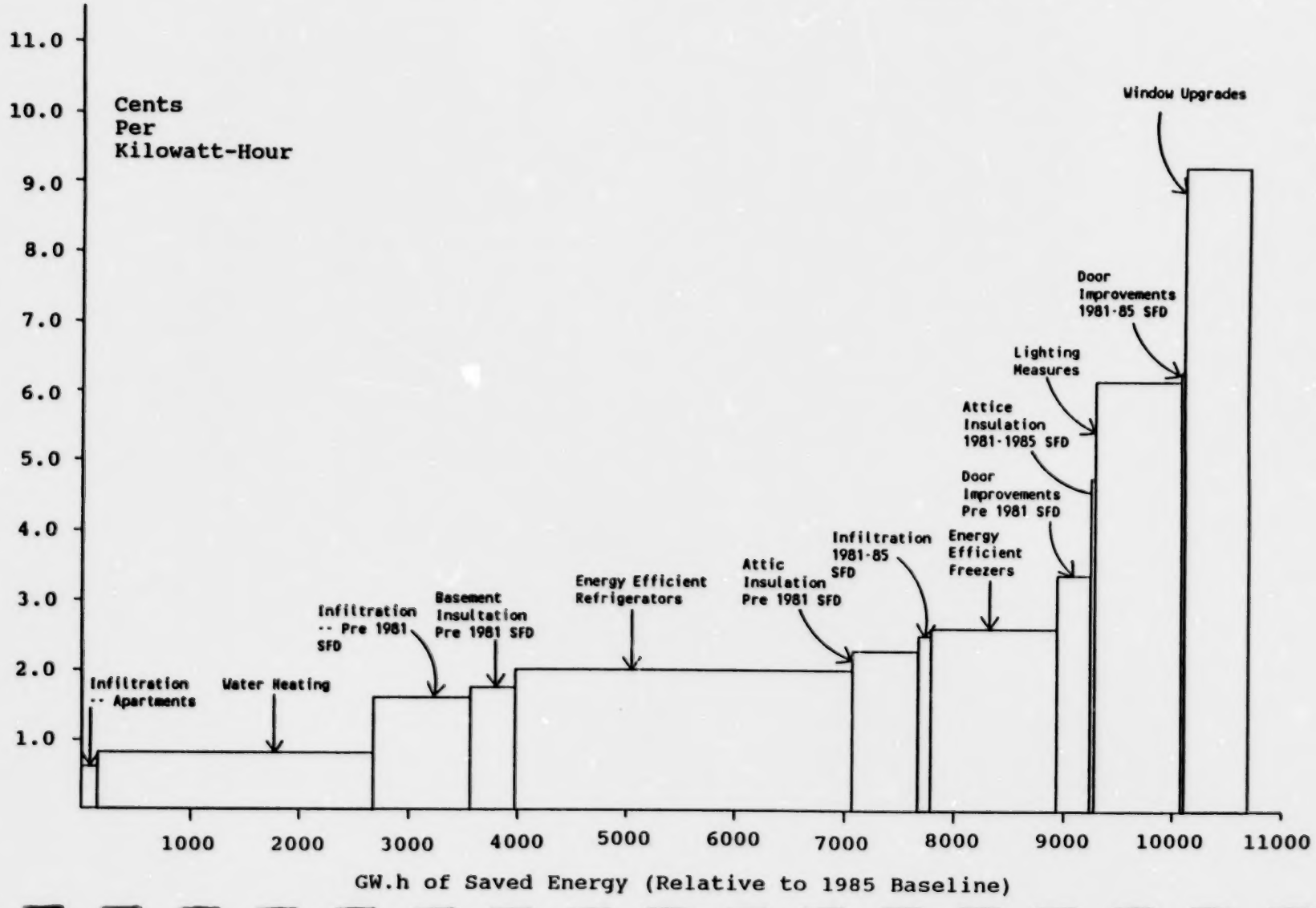
The details of the calculations for the residential sector are contained in Appendix C. Listed in order of increasing unit cost, the conservation blocks computed in Appendix C are as follows:

Block	Measure	Unit Cost (¢/kW.h)	Saving (GW.h)
R12	Infiltration -Apts	0.6	150
R13	Water Heating	0.8	2530
R05	Infiltration Pre - 81 SFD	1.6	885
R07	Basement Insulation Pre - 81 SFD	1.8	413
R01	Energy Eff. Refrigerators	2.0	3095
R04	Attic Insulation Pre - 81 SFD	2.3	590
R10	Infiltration Improvements 81-85 SFD	2.5	115
R02	Energy Eff. Freezers	2.6	1164
R06	Door Improvements Pre-81 SFD	3.4	295
R09	Attic Insulation 81-85 SFD	4.4	44
R03	Lighting	6.2	792
R11	Door Improvements 81-85 SFD	6.3	32
R08	Window Upgrades	9.3	590

The measures are presented in the form of a supply curve for the residential sector in Figure 4.3

FIGURE 4.3

ELECTRICITY CONSERVATION SUPPLY CURVE FOR ONTARIO RESIDENTIAL SECTOR



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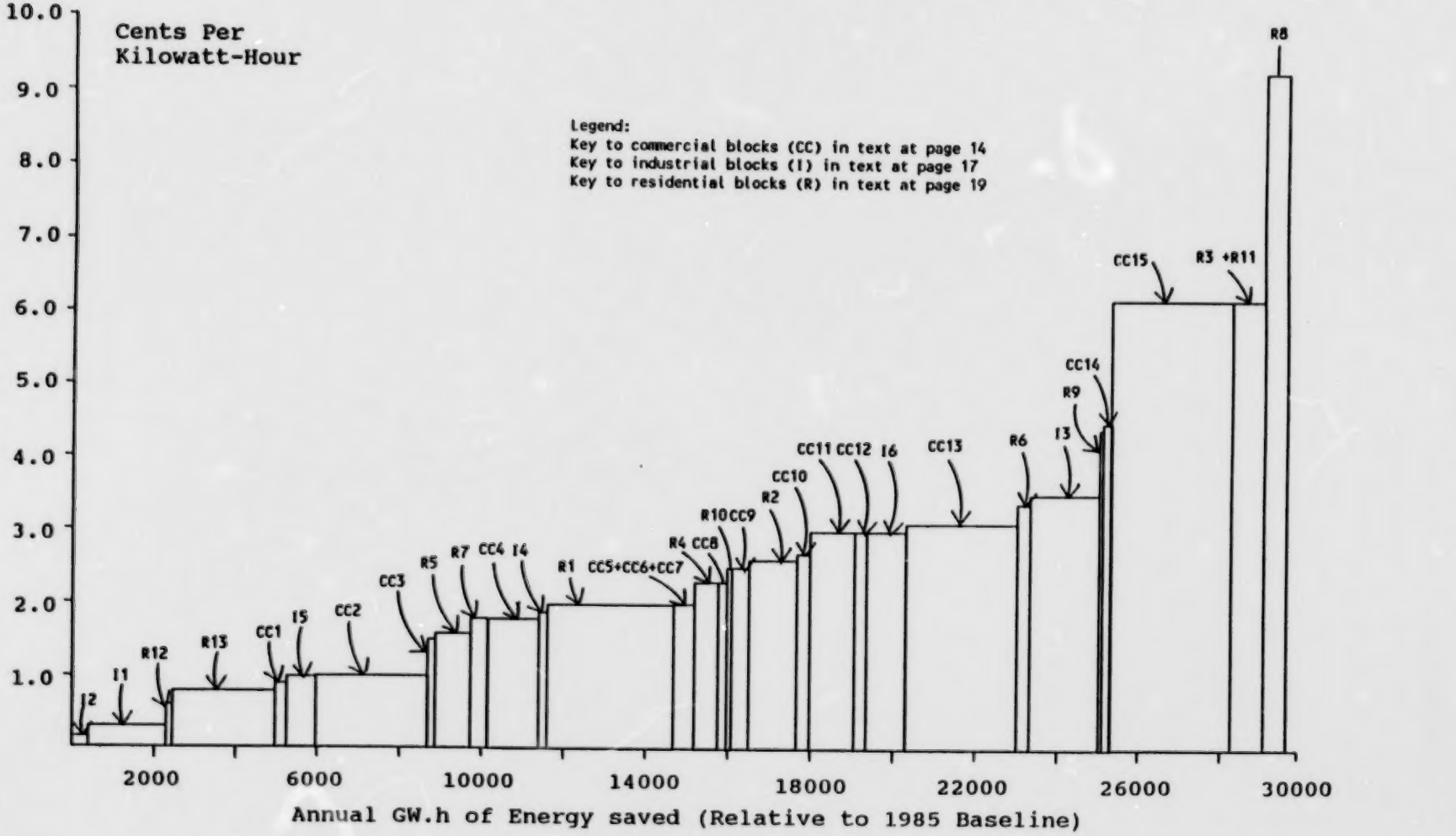
4.4 Composite Curve

Although the quality of the input data and the level of analytical effort varies from sector to sector, we have combined the results of the three sectoral analyses onto one supply curve for electricity conservation in Figure 4.4. The blocks on the curve are the same as for the sectoral curves. In order of increasing unit cost, they are:

BLOCK	ORIGIN	UNIT COST	SAVINGS
1	I2	0.15	400
2	I1	0.3	1900
3	R12	0.6	150
4	R13	0.8	2530
5	CC1	0.9	288
6	I5	1.0	715
7	CC2	1.0	2749
8	CC3	1.5	152
9	R5	1.6	885
10	R7	1.8	413
11	CC4	1.8	1259
12	I4	1.9	200
13	R1	2.0	3095
14	CC5	2.0	305
15	CC6	2.0	35
16	CC7	2.0	162
17	R4	2.3	590
18	CC8	2.3	212
19	R10	2.5	115
20	CC9	2.5	430
21	R2	2.6	1164
22	CC10	2.7	852
23	CC11	3.0	540
24	CC12	3.0	294
25	I6	3.0	960
26	CC13	3.1	2749
27	R6	3.4	295
28	I3	3.5	1700
29	R9	4.4	44
30	CC14	4.5	250
31	CC15	6.2	2935
32	R3 + R11	6.2	820
33	R8	9.3	590

FIGURE 4.4

COMPOSITE ELECTRICITY CONSERVATION SUPPLY CURVE FOR ONTARIO



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5. CONCLUSIONS

5.1 The conservation "supply curve" is a useful tool for visually presenting the costs and potential magnitude of electricity conservation in the society, but care must exercised in interpreting the results, and especially in comparing them with conventional supply curves. Conservation, or electricity productivity improvement, is a much more complex and disaggregate entity than, say, the supply of power plants. For example, we had set out to develop the curves based on conservation measures, but realized during the analysis that the unit cost of a particular measure can vary greatly from one building type to another. Essentially, conservation supply curves show the levelized unit cost of saving electrical energy. The correct figures to compare them with would be the levelized cost of supplying electricity and the life cycle costs of switching to other fuels (where feasible).

5.2 Given the broad qualifications in 5.1, it remains the case that the curves do show a very significant economic potential for electricity conservation and are graphic illustrations of the failure of the market to allocate resources efficiently. The potential for savings are spread throughout the economy, but there are some cells in the end use - subsector - measure space that are particularly rich in potential.

Total evident potential for the measures studied in this report that would be cost effective at 5 ¢/kW.h or less amounts to 26,000 Gw.h, or nearly 25% of the electrical consumption in Ontario in the base year (1985). Of this total, roughly 42% was found in the commercial sector, 23% in the industrial sector, and 35% in the residential sector.

5.3 Because of the extent of detail available on the commercial sector, the savings are more widely distributed than in other sectors, and the curve is smoother than for the other sectors, more truly representing the nature of conservation opportunities. The bulk of the savings come either from improvements in lighting systems or the efficiency and use patterns of motors. The lowest cost blocks are dominated by large office and retail buildings, mostly from simple changes in fluorescent lighting and improved motors. For blocks that represent the use of special measures, subsectors that otherwise show relatively small savings can rise to prominence. For example, hotels and restaurants dominate the savings from the use of compact fluorescents, and the food retail subsector from efficient refrigeration. Utilization

factors and building characteristics are very important determinants of the unit cost of lighting measures.

5.4 Only six general measures were investigated in the industrial sector. Each offered savings in the range of 200 to 2000 GW.h. Costs range from less than 1¢/kW.h to 3.5¢/kw.h. Nearly 40% of the savings can be achieved at costs of less than 0.5¢/kW.h through process controls, instrumentation and waste heat recovery. Lighting, which is responsible for such large savings in the commercial sector, also offers 30% of the savings in the industrial sector; another 30% comes from energy efficient and variable speed motors.

5.5 The bulk of the savings for the residential sector are found to be cost effective below 3 ¢/kW.h, which suggests that it would be worth investigating additional measures in the 3¢/kW.h to 5¢/kW.h range beyond those described here. Of the total 9000 GW.h of savings, nearly half (47%) come from improvements in the efficiency of two appliances, refrigerators and freezers, at a cost of 2 to 2.5 ¢/kW.h. The techniques are well known and already on the market. The next largest share of savings (27%) comes from improvements in electric water heating, all of which are available at costs under 1 ¢/kW.h. The remaining savings are rather widely distributed over various ways to reduce infiltration, add insulation and improve lighting efficiency.

5.6 The savings identified here are incomplete. As emphasized above, this potential represents a selection of technologies, the more important technologies to be sure, but certainly well below the full potential for conservation. Also, as defined, this potential incorporates only those technologies applicable to retrofitting existing systems; new buildings, plant and equipment, and housing could be built to still more efficient levels at the same or lower levels of cost effectiveness.

5.7 Further work related to the conservation supply curves for Ontario should proceed in several directions, but should not necessarily be designed to "refine" the curves presented in this report. In our opinion, macro conservation supply curves are best seen as general indicators, and as a technique for suggesting directions for conservation policy. We also recommend against the use of conservation supply curves for determining the level of conservation potential in future years. Efforts to calculate conservation supply curves for future years require very difficult estimates about what the

baseline consumption will be in future years and, to the extent it is lower than the present, how much of the reduction is due to the conservation measures being analyzed for the curve.

5.8 It would be worthwhile to compare these curves with others that have been prepared for Ontario or for other jurisdictions to see whether important blocks seem to have been omitted or whether the cost or volume of savings for specific blocks seems to be out of line. For example, most of the curves developed by Lovins incorporate substantial savings at negative marginal cost; it would be useful to know whether the absence of such sectors in our results is due to the greater conservatism in our analysis or the neglect of important opportunities. Exactly the same comment applies in areas such as industrial electricity conservation where some analysts have found savings to be much lower than identified here.

5.9 Given the potential identified here, it is relevant to ask how much of that potential is likely to be realized under existing market and institutional conditions over the next five and ten years. In this way, the basic design of and extent of the need for a conservation program will be identified.

5.10 It would be instructive to develop curves for the conservation of peak power requirements. We have not applied load factors to the measures but it would be a relatively straightforward task to do so. There would be other measures that would be interesting to include on such a "power conservation" curve -- in particular, load management and peak flattening techniques.

APPENDIX A -- COMMERCIAL SECTOR CALCULATIONS

APPENDIX A -- COMMERCIAL SECTOR CALCULATIONS

A.1 Base Year Electricity Use

A disaggregation of electricity use in 1985 by building type and end use was developed from a calibration of the Ministry of Energy's commercial sector demand model [MARBEK 1987], combined with building size information from recent analysis by Engineering Interface Limited [EIL 1987]. The resulting disaggregation of 1985 electricity use by 16 building types (plus a residual category) and six end uses is shown in Table A.1. All motor energy, including fans and pumps, is shown as one end use category, although the analysis considered ventilation fans and pump motors separately for many of the building types. The "equipment" category refers to non-motor electrical end uses. Electricity used to run cooling equipment has been kept as a separate end use category, but does not include air circulation. The table also includes estimates for the electricity intensity and floor area shares for electric space and water heating.

In the case of office buildings and retail buildings, the total floor area has been divided into small and large buildings, according to the EIL estimates. For office buildings, small buildings are those with less than 4650 m^2 (50,000 ft^2), and are assumed to account for 47% of the estimated office building floor area. For retail buildings, small buildings are those with less than 465 m^2 (5000 ft^2 and are assumed to account for 18% of the estimated non-food retail floor area.

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ONTARIO COMMERCIAL SECTOR ELECTRICITY USE IN 1985, BY BUILDING TYPE AND END USE

BUILDING TYPE	LIGHTING	MOTORS	COOLING	EQUIPMENT	SPACE HEAT	WATER HEAT	TOTAL
Small Office							
kW.h/sqm	86.11	57.04	17.22	16.15	122.70	7.80	
sqm(10e6)	17.67	17.67	17.67	17.67	5.26	5.26	
GW.h	1521.33	1007.74	304.23	285.33	645.40	41.03	3805.06
Large Office							
kW.h/sqm	129.17	80.73	23.68	16.15	N/A	N/A	
sqm(10e6)	19.92	19.92	19.92	19.92			
GW.h	2573.42	1608.36	471.77	321.75			4975.30
Small Retail							
kW.h/sqm	193.75	77.50	40.90	32.29	192.68	27.80	
sqm(10e6)	3.24	3.24	3.24	3.24	0.49	0.65	
GW.h	627.19	250.88	132.40	104.53	93.56	18.00	1226.54
Large Retail							
kW.h/sqm	139.93	68.89	33.37	32.29	192.68	27.80	
sqm(10e6)	14.75	14.75	14.75	14.75	2.21	2.21	
GW.h	2063.52	1015.91	492.10	476.17	426.21	61.49	4535.41
Food Stores							
kW.h/sqm	139.93	386.75	33.37	32.29	206.00	53.38	
sqm(10e6)	4.63	4.63	4.63	4.63	1.76	1.76	
GW.h	647.36	1789.22	154.38	149.38	362.15	93.84	3196.33
Element. School							
kW.h/sqm	37.67	26.91	0.00	5.38	191.82	10.01	
sqm(10e6)	11.58	11.58	11.58	11.58	0.00	0.00	
GW.h	436.29	311.67	0.00	62.31	0.00	0.00	810.28
Second. School							
kW.h/sqm	51.67	33.91	3.23	8.07	191.82	10.01	
sqm(10e6)	5.00	5.00	5.00	5.00	0.00	0.00	
GW.h	258.35	169.55	16.15	40.35	0.00	0.00	484.40
Colleges							
KW.h/sqm	83.46	48.81	12.60	12.60	177.92	77.84	
sqm(10e6)	1.50	1.50	1.50	1.50	0.19	0.19	
GW.h	124.86	73.02	18.85	18.85	34.60	15.14	285.32
Universities							
KW.h/sqm	92.93	31.56	14.03	14.03	177.92	77.84	
sqm(10e6)	5.18	5.18	5.18	5.18	0.67	0.67	
GW.h	480.91	163.32	72.61	72.61	119.70	52.37	961.51
Motel							
KW.h/sqm	82.35	62.43	23.98	31.21	150.00	50.00	
sqm(10e6)	0.45	0.45	0.45	0.45	0.45	0.45	
GW.h	36.73	27.84	10.70	13.92	66.90	22.30	178.39

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ONTARIO COMMERCIAL SECTOR ELECTRICITY USE IN 1985, BY BUILDING TYPE AND END USE (continued)

BUILDING TYPE	LIGHTING	MOTORS	COOLING	EQUIPMENT	SPACE HEAT	WATER HEAT	TOTAL
Hotel							
KW.h/sqm	96.88	110.87	30.14	31.21	194.60	44.48	
sqm(10e6)	4.17	4.17	4.17	4.17	0.83	2.08	
GW.h	403.94	462.27	125.67	130.13	162.28	92.73	1377.02
Restaurant							
kW.h/sqm	136.22	48.80	38.92	389.20	194.60	116.76	
sqm(10e6)	5.68	5.68	5.68	1.42	0.14	0.36	
GW.h	774.14	277.33	221.18	552.96	27.65	41.47	1894.73
Hospital							
KW.h/sqm	91.49	53.82	21.53	21.53	194.60	0.00	
sqm(10e6)	6.95	6.95	6.95	6.95	1.39	0.00	
GW.h	636.14	374.20	149.68	149.68	270.60	0.00	1580.30
Warehouse							
kW.h/sqm	26.00	20.23	7.78	0.00	210.45	1.95	
sqm(10e6)	22.31	22.31	22.31	22.31	0.67	22.31	
GW.h	579.93	451.23	173.53	0.00	140.82	43.49	1389.01
Recreation							
kW.h/sqm	80.00	126.19	6.67			23.63	
sqm(10e6)	4.61	4.61	4.61	4.61	4.61	2.31	
GW.h	368.80	581.74	30.75	0.00	0.00	54.47	1035.75
Religion							
kW.h/sqm	47.00	28.57	6.12			25.02	
sqm(10e6)	3.95	3.95	3.95	3.95	3.95	1.98	
GW.h	185.65	112.85	24.16	0.00	0.00	49.41	372.07
Other							
kW.h/sqm	50.00	80.00	36.14		194.60	44.48	
sqm(10e6)	10.00	10.00	10.00	10.00	10.00	5.00	
GW.h	500.00	800.00	361.40	0.00	1946.00	222.40	3829.80
TOTAL							
GW.h	12218.55	9477.13	2759.55	2377.96	4295.87	808.15	31937.21

A.2 Conservation Measures

The following generic information for a set of conservation measures was used to analyze their costs and impacts for each of the building types.

A.2.1 Fluorescent Lighting

The basic unit for analysis of energy conservation in fluorescent lighting is the four-foot two-40W lamp luminaire. This is a significant conservatism, as several of the measures considered would show economies of scale when applied to larger luminaires.

The Level One measures for fluorescent lighting consist of replacing the 40W lamps with first generation energy efficient lamps (drawing 34 Watts) and the ballasts with first generation efficient core ballasts (drawing 10 Watts instead of the conventional 16W). Combined with the ballast savings due to the lower wattage lamps, the total savings are about 25% of the baseline technology (40W lamps, 16W ballast). The lighting level is reduced 7% to 12%. A $10 premium and 20 year lifetime are assumed for the ballast and a $1.50 premium (75¢ each) and five year lifetime for the lamps [MARBEK 1986]. The resulting annualized cost of $1.07 per fixture is then applied to the particular conditions for each building type to determine overall potential and cost by building type.

The Level Two measures for fluorescent lighting include adding an annodized aluminum reflector to the luminaire, which allows half of the lamps to be eliminated. The remaining lamps are replaced with high performance 40W lamps to ensure lighting levels are maintained. The premium for the lamps is assumed to be equal to the savings from lamp elimination (premium for high performance lamps can be as high as $2/lamp). The reflectors are assumed to have a $50 cost [MARBEK 1986] and a 20 year lifetime. The electricity savings from the reflectors result from the lamp elimination. Compared to the baseline energy use, the reflector and the high performance lamps would deliver the same lighting level with about 50% of the electricity (assuming efficient core ballasts are included). When implemented subsequent to the Level One measures, the installation of the reflectors and high performance lamps cut electricity use by about 32%, although this could be increased to 50% if the low wattage lamps (and consequent lower light levels) were maintained.

The Level Three measures for fluorescent lighting include installation of electronic, dimmable ballasts with photocell controls, reflectors and high performance 40W lamps. It is

assumed that the electronic ballast and photocell controls would be installed at the same time as the reflector. A total cost of $115 per luminaire is assumed for the ballast and reflector (installed), or a $65 premium for the ballast [MARBEK 1986]. The photocell controllers are assumed to cost $200 each, installed [RMI 1986, LBL 1985]. Each photocell controller controls the light output of four or eight luminaires, depending on the building type and size. The combination of the dimmable ballast and the photocell controller allows electricity savings from compensation for lumen depreciation over the life of the lamp and daylighting, which depends on the perimeter/core ratio and window area. Total electricity savings relative to the baseline with this package of measures can be as high as 85%.

The impact of these measures on heating and cooling electricity requirements will affect the total savings and unit costs of lighting electricity conservation measures. These impacts will depend on the type and size of building and are particularly sensitive to the presence or absence of an economizer in the building cooling system [EIL 1986]. We have used the following assumptions in computing the cooling and heating (electric heated buildings only) impacts of lighting conservation measures, based on the EIL analysis for small and large office and retail buildings [EIL 1986]:

Building Type	For each kW.h reduction in internal load	
	Heating energy increase (kW.h)	Cooling energy decrease (kW.h)
Small office	0.32	0.10
Large office	0.24	0.13
Small Retail	0.31	0.15
Large Retail	0.31	0.15
All others	0.30	0.10

A.2.2 Compact Fluorescents

We have assumed that where incandescent light bulbs can bereplaced by compact fluorescents, the cost will be $22 per bulb, with a 10,000 hour lifetime. The resulting amortization period will thus depend on the hours of usage for the bulb being replaced. The percentage of lighting from incandescent bulbs in the baseline energy use is based on the

"typical building" analysis done by Engineering Interface for Ontario Hydro [EIL 1986].

A.2.3 Motors -- Balancing

The cost and savings figures from [EIL 1986] were used to compute fan and pump motor electricity savings due to air and water balancing, respectively. The savings per unit floor area were multiplied by total floor area by building type to estimate total savings from these measures.

A.2.4 Energy Efficient Motors

Cost premiums and electricity savings for the replacement of electric motors by energy efficient motors are taken from the Engineering Interface analysis [EIL 1986]. Total savings potential for a particular building type are calculated from the total floor area estimate (Table A.1) and the savings per unit floor area.

A.2.5 Motor Scheduling

Costs per unit floor area and electricity savings for motor scheduling are taken from [EIL 1986]. Investments are amortized over ten years and the total savings are calculated using the building type floor areas from Table A.1.

A.2.6 Cooling

The cost effectiveness and impact of conservation measures for cooling equipment are highly variable from one building to the next and also depend on the internal load reductions achieved by other conservation measures that reduce the internal heat gain in the building. In their technology review, Engineering Interface [EIL 1987] suggest a life cycle efficient chiller will save 18% compared to the standard selection chiller, with the 10% premium cost having an average payback in the order of 5 years or less (equivalent with our costing method to about 2¢/kW.h). In the case of high efficiency unitary cooling equipment, premiums of 10 to 15% are typical, with savings averaging 12% and paybacks 2 to 3 years. We have assumed that 18% and 12% savings can be achieved for 2¢/kW.h (premium) with high efficiency central and unitary cooling equipment, respectively.

A.2.7 Space Heating - Glazing

For space heated buildings the only conservation measure we have included is window glazing. Using a cost of $3/ft^2 of window area and a lifetime of 10 years, we have assumed the application of such glazing could reduce space heating

requirements by 20% [EIL 1986]. Total window area is estimated from the EIL "typical building" analysis.

A.2.8 Water Heating

We were not able to find any detailed cost and performance estimates for efficiency improvements in water heating systems in commercial buildings, although there is certainly a large potential for energy savings here. Some measures and their estimated savings include improved heater efficiency (5-15%), upgrading of tank and pipe insulation (15-40%), temperature reduction (5-20%), and scheduling of the re-circulation pumps during periods of low demand (15-20%). We have assumed an overall savings of 20% is achievable for 2¢/kW.h or less.

A.3 Calculation of Supply Curve Components

This section includes the details of the calculations of electricity conservation potential available through the measures described above. The calculations are defined in "blocks", with each block referring to a certain total amount of electricity that can be saved (in GW.h) and a corresponding cost in ¢/kW.h.

BLOCK:	C1
BUILDING TYPE:	Small Offices - Electric Heated
MEASURE:	Fluorescent Lighting -- Level One
SAVINGS (GW.h):	88.3
UNIT COST (¢/kW.h):	1.64

EXPLANATION: An annualized cost of $1.073 per two lamp (92W) fixture saves 25% of electricity for fluorescent lighting. An annual use of 3640 hours, this amounts to 83.72 kW.h per fixture per year. Assuming fluorescent lighting to provide 95% of a 2.2 W/ft^2 lighting load, and with 5.26 X 10^6 m^2 of electric heated small office floor area, the total lighting savings amount to 113.232 GW.h at 1.28¢/kW.h. This is modified by a reduction in electricity requirements for cooling of 10% of lighting energy savings and an increase in heating requirements of 32% of lighting energy savings, for a net saving of 88.32 GW.h at 1.64¢/kW.h.

BLOCK:	C2
BUILDING TYPE:	Small Offices - Fuel Heated
MEASURE:	Fluorescent Lighting - Level 1
SAVINGS (GW.h):	293.9
UNIT COST (¢/kW.h):	1.17

EXPLANATION: The calculations are similar to Block C1 except the floor area is 12.41 X 10^6 m^2 and the heating impacts do not affect the electricity savings. The unmodified lighting savings are 267.2 GW.h at 1.28 ¢/kW.h. The additional savings in cooling electricity requirements (10% of lighting electricity savings) result in net savings of 293.9 GW.h at 1.17¢/kW.h.

BLOCK: C3
BUILDING TYPE: Small Offices - Electric Heated
MEASURE: Fluorescent Lighting - Level 2
SAVINGS (GW.h): 88.3
UNIT COST (¢/kW.h): 5.6
EXPLANATION: The addition of the reflector (lifetime of 20 years) with an annualized cost of $3.68 per fixture results in the same savings as the Level 1 measures. The cost of the premium bulbs is cancelled by the savings resulting from the reduced number of bulbs required

BLOCK: C4
BUILDING TYPE: Small Office - Fuel Heated
MEASURE: Fluorescent Lighting - Level 2
SAVINGS (GW.h): 293.9
UNIT COST (¢/kW.h): 4.0
EXPLANATION: The same calculations as for the electric heated buildings (C3) except for the impact on heating requirements.

BLOCK: C5
BUILDING TYPE: Small Office - Electric Heated
MEASURE: Fluorescent Lighting - Level Three
SAVINGS (GW.h): 117.5
UNIT COST (¢/kW.h): 9.3
EXPLANATION: The premium for the dimmable electronic ballast (assuming it is installed at the same time as the reflector) is $65, and a twenty year lifetime is assumed for an annualized cost per fixture of $4.78. In small offices, the photocell controllers are assumed to be control four luminaires, implying an installed cost of $50 per fixture or $3.68 annualized. Thus the combined marginal cost for the Level Three measures is $8.46 per fixture. As compared to the baseline electricity consumption of 335 kW.h per fixture, the combined effect of savings from the reflector and dimmable ballast system could reduce this by 85% in small building with a high perimeter/core ratio. This high level of savings is the result of the combination of savings due to compensation for daylighting, task tuning, compensation for lumen depreciation, improved voltage and lampwall temperature stability, the intrinsic savings from the lamp/ballast

combination, and the increased luminaire output due to the reflector. To avoid double counting, we attribute only the marginal savings of 117 kW.h per fixture (over and above the savings from Level One and Level Two measures) to the investment in Level Three technology. After allowance for heating and cooling impacts, the net unit cost is 9.3 ¢/kW.h, and the total savings amount to 117.5 GW.h.

BLOCK:	C6
BUILDING TYPE:	Small Office - Fuel Heated
MEASURE:	Fluorescent Lighting - Level 3
SAVINGS (GW.h):	355.3
UNIT COST (¢/kW.h):	6.6
EXPLANATION:	The calculations are the same as for Block C5 except for the heating impacts of the lighting conservation measures.

BLOCK:	C7
BUILDING TYPE:	Small Office - Electric Heat
MEASURE:	Compact Fluorescents
SAVINGS (GW.h):	6.6
UNIT COST (¢/kW.h):	3.7
EXPLANATION:	Assuming that 5% of the lighting in small offices is due to incandescent bulbs with an average wattage of 100W and annual usage of 3640 hours, then compact fluorescents at $22/bulb (lifetime n=3 years) have an annualized cost of $7.93 and can save 75% of the electricity requirements of those bulbs they replace. This yields lighting energy savings of 8.5 GW.h at 2.9¢/kW.h and net savings, after heating and cooling effects, of 6.6 GW.h at 3.7¢/kW.h.

BLOCK:	C8
BUILDING TYPE:	Small Office - Fuel Heated
MEASURE:	Compact Fluorescents
SAVINGS (GW.h):	22.0
UNIT COST (¢/kW.h):	2.64
EXPLANATION:	Calculations as for Block C7 except for heating impacts and applicable floor area.

BLOCK:	C9
BUILDING TYPE:	Small Office
MEASURE:	Motors -- Balancing
SAVINGS (GW.h):	148.0
UNIT COST (¢/kW.h):	3.00
EXPLANATION:	Using Engineering Interface's typical small office building [EIL 1986], motor load is assumed to be divided between ventilation fans (0.67 W/ft^2 and 3000 hours

per year operation) and other motors (0.38 W/ft^2 and 8760 hours per year operation). Motor electricity use of 5.3 kW.h/ft^2 can be reduced at an initial cost of 19¢/ft^2 to achieve a 14.6% saving. Assuming a ten year lifetime for such measures, an annualized investment of 2.34¢/ft^2 yields an annual saving of (.146 X 5.338 kW.h)/ft^2 for a unit cost of 3.0¢/kW.h. The total potential for small offices is 14.6% of the base year motor use of 1007.7 GW.h.

BLOCK: C10
BUILDING TYPE: Small Office
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 55.9
UNIT COST (¢/kW.h): 0.79
EXPLANATION: The calculations for this measure assume that the balancing (Block C9) has already been performed. Although the premium cost of energy efficient motors is small relative to the unit cost of the balancing, the total cost of motor replacement is high and so the measure would not be expected to precede balancing, even though its unit cost is smaller. Engineering Interface use a figure of $35/kW as the premium cost for energy efficient motors, and assume that an average savings of 6.5% per motor can be achieved in small offices by replacing worn out or damaged motors with energy efficient models. If these motors are assumed to have a lifetime of 20 years, then the annualized premium cost of replacement is 0.1729¢/ft^2 for a savings of .22 kW.h/ft^2, or a unit annualized cost of only 0.79¢/kW.h.
The total savings, assuming balancing savings have already been taken, amounts to 55.9 GW.h in the base year stock of small office buildings.

BLOCK: C11
BUILDING TYPE: Small Office
MEASURE: Motor Scheduling
SAVINGS (GW.h): 228
UNIT COST (¢/kW.h): 3.06
EXPLANATION: The scheduling of motor operations can yield very large savings in electricity. At a cost of 30¢/ft^2 (annualized to 3.69c//ft^2 at n=10), electricity savings of 1.21 kW.h/ft^2 can be achieved, or 28%. This yields a total potential for small office buildings of 228 GW.h at a unit cost of 3.06¢/kW.h.

BLOCK: C12
BUILDING TYPE: Small Offices
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 22.0
UNIT COST (¢/kW.h): 2.52
EXPLANATION: We assume that 12% savings can be achieved in the small office subsector, corresponding to the prevalence of unitary cooling equipment in these buildings. The savings will depend on the extent to which cooling load has already been reduced by lighting savings and other measures that reduce the internal building cooling load. We have calculated the implications for the fluorescent lighting conservation measures only, but they dominate the interactive effect. Before any load reductions, a 12% saving at 1.8¢/kW.h would correspond to a total potential in this subsector of 36.5GW.h. Implementation Level One measures (Block C1 and Block C2) would reduce the potential to 32 GW.h and increase the unit cost to 2.0¢/kW.h. Level Two measures (Blocks C3 and C4) reduce potential to 28 GW.h and increase the unit cost to 2.23¢/kW.h. Level Three measures (Blocks C5 and C6) reduce the potential to 22 GW.h and increase the unit cost to 2.5 c//kW.h. We have used the savings and unit costs associated with Level Three lighting conservation measures.

BLOCK: C13
BUILDING TYPE: Small Office -- Electric Heated
MEASURE: Space Heating -- Window Glazing
SAVINGS (GW.h): 152.0
UNIT COST (¢/kW.h): 1.51
EXPLANATION: Here we have used EIL's typical small office building and assumed 25% of the wall area is window and the energy efficient glazing costs \$3/ft^2 of window area. Thus a typical small building with 3500 ft^2 of window area would cost \$10,500 to glaze and estimated savings of 20% amount to 85,493 kW.h/year (assuming space heat requirements of 122.7 kW.h/m^2 or 11.4 kW.h/ft^2). Assuming a lifetime of ten years, this yields a CCE of 1.51¢/kW.h and a total potential in the subsector of 152 GW.h.

BLOCK: C14
BUILDING TYPE: Large Office
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 690.5
UNIT COST (¢/kW.h): 0.80
EXPLANATION: A lighting load of 2.4 W/ft^2 is assumed to be 95% fluorescent, and annual average usage is assumed to be 5200 hours. The fixture and annualized cost per fixture as assumed for small office buildings is assumed here, but the unit cost of the savings is smaller due to the higher

utilization factor for lighting in large buildings. The lighting savings amount to 611 Gw.h from Level One measures at a unit cost of 0.90¢/kW.h, but the reduction in cooling load (13% of lighting savings) increases the savings to 690.5 GW.h and reduces the unit cost to 0.80¢/kW.h.

BLOCK: C15
BUILDING TYPE: Large Office
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 690.5
UNIT COST (¢/kW.h): 1.4
EXPLANATION: Similar calculation to Block C4 except for greater base level intensity and cooling credit of 13% of lighting savings.

BLOCK: C16
BUILDING TYPE: Large Office
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 966.9
UNIT COST (¢/kW.h): 3.49
EXPLANATION: The annualized cost of the reflector is the same as for Block C4 but the photocell controllers are assumed in large buildings to be distributed one for every eight luminaires, reducing their initial cost to $25 per luminaire and their annualized cost to $1.84 per fixture. The total annualized costs for the Level Three measures are therefore $6.62 per fixture. Total savings are assumed to be 85% or 407 kW.h per fixture, but only 168 kW.h per fixture are attributed to the incremental investment in the Level Three technology. The resulting lighting savings are 855.7 GW.h at 3.94¢/kW.h, and the credit for cooling saving increases the total savings to 966.9 GW.h and reduces the units cost to 3.49¢/kW.h.

BLOCK: C17
BUILDING TYPE: Large Office
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 56
UNIT COST (¢/kW.h): 2.65
EXPLANATION: It is assumed 5% or 129 GW.h of large office building lighting is incandescent, and that compact fluorescents at $22 each (average wattage of incandescent 100 W) can replace half the incandescent bulbs and save 75% of the electricity. Because of the higher utilization factor (as compared to small offices), the compact fluorescents are assumed to last for only two years, boosting the unit cost of the saved lighting energy to 3.0¢/kW.h. The credit for

cooling load reduction results in total savings of 56 GW.h and reduces the unit cost to 2.65¢/kW.h

BLOCK: C18
BUILDING TYPE: Large Office
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 322
UNIT COST (¢/kW.h): 1.27
EXPLANATION: Using Engineering Interface's typical large office building [EIL 1986], with 0.70 W/ft^2 for fan motors (at 5000 hours of operation per year) and 0.46 W/ft^2 of other motors (at 8760 hours of operation per year), an investment of 15.5¢/ft^2 in balancing will yield savings of 20%. Annualized over ten years, this yields a unit CCE of 1.27¢/kW.h and total savings of 322 GW.h.

BLOCK: C19
BUILDING TYPE: Large Office
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 83.6
UNIT COST (¢/kW.h): 0.61
EXPLANATION: This is a similar calculation to that for Block C10, with 75% of the motors being replaced with energy efficient models at a premium of $35/kW and with the savings calculated assuming air and water system balancing to already have been carried out.

BLOCK: C20
BUILDING TYPE: Large Office
MEASURE: Motor Scheduling
SAVINGS (GW.h): 139.4
UNIT COST (¢/kW.h): 1.90
EXPLANATION: Similar calculation to Block C11 except initial cost is 10¢/ft^2 (annualized at n=10 to 1.23¢/ft^2) and savings are 11.5% of post-balancing, post-replacement consumption.

BLOCK: C21
BUILDING TYPE: Large Office
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 36
UNIT COST (¢/kW.h): 2.82
EXPLANATION: We assume that 18% savings can be achieved here corresponding to the prevalence of central cooling systems. While this level of saving can be achieved for an estimated 1.8¢/kW.h, the effect of lighting conservation measures is to reduce the total potential and increase

the unit cost. The savings potential and unit costs after Level One, Two and Three fluorescent lighting conservation measures, respectively, are 70.6 GW.h at 2.1¢/kW.h, 55 GW.h at 2.4¢/kW.h, and 36 GW.h at 2.82¢/kW.h.

BLOCK: C22
BUILDING TYPE: Small Retail
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 171
UNIT COST (¢/kW.h): 0.78
EXPLANATION: The standard annualized cost of $1.07 per fixture is applied to a lighting load of 3.5/ft^2 and estimated utilization of 5140 hours per year. Resulting lighting savings are 150 GW.h (assuming 95% fluorescent as per EIL typical small retail building) at a unit cost of 0.9¢/kW.h. A cooling credit of 15% increases the savings to 171 GW.h and decrease the unit cost to 0.78¢/kW.h.

BLOCK: C23
BUILDING TYPE: Small Retail
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 171
UNIT COST (¢/kW.h): 2.70
EXPLANATION: As with similar calculations for office buildings, this measure doubles the savings achieved through Level One measures. The unit cost of the lighting savings is 3.11¢/kW.h, which is reduced by 15% due to the cooling credit.

BLOCK: C24
BUILDING TYPE: Small Retail
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 119.2
UNIT COST (¢/kW.h): 7.78
EXPLANATION: The implementation of Level Three measures is assumed to save 70% of the electricity requirements, relative to the baseline. A somewhat lower level of savings has been assumed compared to office buildings because of the low potential for daylighting in this subsector. Each photocell controller controls four luminaires, so the incremental annualized cost of the Level Three measures is the same as for Block C5, or $8.46. The utilization factor of 0.59 yields a unit cost for the lighting savings of 8.9¢/kW.h, which is reduced to 7.78¢/kW.h after the cooling credit. The total incremental savings attributed to the Level Three measures in this sector are 119.2 GW.h.

BLOCK: C25
BUILDING TYPE: Small Retail
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 34.9
UNIT COST (¢/kW.h): 3.29
EXPLANATION: Using Engineering Interface's typical small retail building [EIL 1986], an investment of 26.67 ¢/ft^2 yields savings of 14% or 1 kW.h/ft^2. Annualized over ten years, the unit cost is 3.29¢/kW.h.

BLOCK: C26
BUILDING TYPE: Small Retail
MEASURE: Energy Efficiency Motors
SAVINGS (GW.h): 10.5
UNIT COST (¢/kW.h): 0.62
EXPLANATION: An investment of 2.53¢/ft^2 annualized over twenty years yields savings of 0.3 kW.h/ft^2 in the typical small retail building

BLOCK: C27
BUILDING TYPE: Small Retail
MEASURE: Motor Scheduling
SAVINGS (GW.h): 48.8
UNIT COST (¢/kW.h): 5.9
EXPLANATION: An investment of 66.6¢/ft^2 annualized over ten years yields savings of 1.4 kW.h/ft^2 in the typical small retail building.

BLOCK: C28
BUILDING TYPE: Small Retail
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 8.3
UNIT COST (¢/kW.h): 2.65
EXPLANATION: A base year cooling energy use of 132.4 GW.h is subject to reductions as a result of the lighting conservation measures. It is assumed that 18% savings of pre-conservation cooling energy can be saved for 1.8¢/kW.h, reflecting the prevalence of unitary cooling equipment in this subsector. After Level One, Two and Three fluorescent lighting conservation measures, the savings potential and unit costs are, respectively, 13.2 GW.h at 2.1¢/kW.h, 10.4 GW.h at 2.4¢/kW.h, and 8.3 Gw.h at 2.65¢/kW.h.

BLOCK: C29
BUILDING TYPE: Large Retail
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 563
UNIT COST (¢/kW.h): 0.78
EXPLANATION: The standard $1.07 per fixture cost is applied to lighting levels which are assumed to be 2.5 W/ft^2 and 95 % fluorescent. The utilization is 5200 hours per year and the cooling credit is 15% of lighting electricity saved.

BLOCK: C30
BUILDING TYPE: Large Retail
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 563
UNIT COST (¢/kW.h): 2.68
EXPLANATION: The annualized cost of $3.68 for the reflector is divided by the 120 kW.h/fixture savings for a unit cost of 3.08¢/kW.h for the lighting savings. This is reduced by 15% due to the cooling credit.

BLOCK: C31
BUILDING TYPE: Large Retail
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 450.9
UNIT COST (¢/kW.h): 6.02
EXPLANATION: The photocell controllers are assumed to control eight fixtures each and the total lighting savings, relative to the base line, are 70%. The lower level is used to reflect the limited potential for daylighting in this subsector. The lighting savings attributed to the marginal improvements from the Level Three technology are 97 kW.h per fixture for a unit cost of 6.9¢/kW.h. This is reduced to 6.02¢/kW.h due to the cooling credit, and the overall incremental savings due to the Level Three measures are 392 GW.h plus the cooling credit, for a total of 450.9 Gw.h.

BLOCK: C32
BUILDING TYPE: Large Retail
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 203
UNIT COST (¢/kW.h): 1.28
EXPLANATION: An investment of 13.3¢/ft^2 (annualized to 1.64¢/ft^2 over ten years) saves 1.28 kW.h/ft^2.

BLOCK: C33
BUILDING TYPE: Large Retail
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 37
UNIT COST (¢/kW.h): 0.63
EXPLANATION: An investment of 2.16¢/ft^2 (annualized to 0.16¢/ft^2 over 20 years) results in savings of 0.25 kW.h/ft^2.

BLOCK: C34
BUILDING TYPE: Large Retail
MEASURE: Motors Scheduling
SAVINGS (GW.h): 154
UNIT COST (¢/kW.h): 1.51
EXPLANATION: An investment of 11.9¢/ft^2 (annualized to 1.47¢/ft^2 over 10 years) saves 0.97 kW.h/ft^2.

BLOCK: C35
BUILDING TYPE: Large Retail
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 34
UNIT COST (¢/kW.h): 2.56
EXPLANATION: Savings of 12% at 1.8¢/kW.h (pre lighting measures), corresponding to the prevalence of unitary cooling equipment in this subsector. After Level One, Two and Three lighting conservation measures the savings potential and units costs are, respectively, 50 Gw.h at 2.07¢/kW.h, 41 GW.h at 2.34¢/kW.h, and 34 GW.h at 2.56¢kW.h.

BLOCK: C36
BUILDING TYPE: Food Retail
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 177
UNIT COST (¢/kW.h): 0.77
EXPLANATION: Cooling credit of 15% is assumed, with 95% fluorescent lighting.

BLOCK: C37
BUILDING TYPE: Food Retail
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 177
UNIT COST (¢/kW.h): 2.68
EXPLANATION: As per Large Retail

BLOCK: C38
BUILDING TYPE: Food Retail
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 141.4
UNIT COST (¢/kW.h): 6.02
EXPLANATION: As per Block C31 for Large Retail

BLOCK: C39
BUILDING TYPE: Food Retail
MEASURE: Motors - Balancing
SAVINGS (GW.h): 63.7
UNIT COST (¢/kW.h): 1.28
EXPLANATION: As per Large Retail

BLOCK: C40
BUILDING TYPE: Food Retail
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 3
UNIT COST (¢/kW.h): 0.63
EXPLANATION: As per Large Retail

BLOCK: C41
BUILDING TYPE: Food Retail
MEASURE: Motors Scheduling
SAVINGS (GW.h): 11.6
UNIT COST (¢/kW.h): 1.51
EXPLANATION: As per Large Retail

BLOCK: C42
BUILDING TYPE: Food Retail
MEASURE: Refrigeration
SAVINGS (GW.h): 294
UNIT COST (¢/kW.h): 3.0
EXPLANATION: In the absence good documentation of savings and costs for the refrigeration load in food retail stores, we have simply assumed that a 20% saving could be achieved for 3¢/kW.h. This is in line with a similar estimate by Ontario Hydro [Ontario Hydro 1986b].

BLOCK: C43
BUILDING TYPE: Food Retail
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 11
UNIT COST (¢/kW.h): 2.56
EXPLANATION: A base cooling load of 154 GW.h is subject to 12% savings at 1.8¢/kW.h, corresponding to the

prevalence of unitary cooling equipment in this subsector. After lighting conservation measures the savings and units costs are 16 GW.h at 2.07¢/kW.h (Level One), 13 GW.h at 2.34¢/kW.h (Level Two) and 11 GW.h at 2.56¢/kW.h (Level Three).

BLOCK: C44
BUILDING TYPE: Elementary Schools
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 103
UNIT COST (¢/kW.h): 1.73
EXPLANATION: The relatively low utilization factor (2700 hours per year) makes the unit cost of lighting savings somewhat higher than for other sectors. Also, no cooling credit applies.

BLOCK: C45
BUILDING TYPE: Elementary Schools
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 103
UNIT COST (¢/kW.h): 5.41
EXPLANATION: As above.

BLOCK: C46
BUILDING TYPE: Elementary Schools
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 145
UNIT COST (¢/kW.h): 10.5
EXPLANATION: As for Block C44.

BLOCK: C47
BUILDING TYPE: Elementary Schools
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 8.2
UNIT COST (¢/kW.h): 3.0
EXPLANATION: Assumes that 50% of the incandescent bulbs can be converted to compact fluorescents with a savings of 75% per bulb.

BLOCK: C48
BUILDING TYPE: Elementary Schools
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 62.3
UNIT COST (¢/kW.h): 3.7
EXPLANATION: A 15¢/ft^2 investment (annualized to 1.85¢/ft^2 over 10 years) saves 0.5 kW.h/ft^2 in the typical school building.

BLOCK: C49
BUILDING TYPE: Elementary Schools
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 12.46
UNIT COST (¢/kW.h): 1.13
EXPLANATION: An investment of 1.53¢/ft^2 (annualized to 0.113¢/ft^2 over 20 years) yields savings of 0.1 kW.h/ft^2.

BLOCK: C50
BUILDING TYPE: Elemnentary Schools
MEASURE: Motors Scheduling
SAVINGS (GW.h): 26.2
UNIT COST (¢/kW.h): 4.87
EXPLANATION: An investment of 8.3¢/ft^2 (annualized to 1.023¢/ft^2 over 10 years) yields savings of 0.2 kW.h/ft^2.

BLOCK: C51
BUILDING TYPE: Secondary Schools
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 61.3
UNIT COST (¢/kW.h): 1.55
EXPLANATION: Utilization 3000 hours per year. Lighting load 95% fluorescent. Cooling credit ignored.

BLOCK: C52
BUILDING TYPE: Secondary Schools
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 61.3
UNIT COST (¢/kW.h): 5.3
EXPLANATION: As for Block C51

BLOCK: C53
BUILDING TYPE: Secondary Schools
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 61.3
UNIT COST (¢/kW.h): 9.6
EXPLANATION: Total savings 75% of baseline electricity intensity for lighting, reflecting intermediate level of daylighting available in this subsector. Photocell controls distributed over 8 fixtures.

BLOCK: C54
BUILDING TYPE: Secondary Schools
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 5 GW.h
UNIT COST (¢/kW.h): 3.0
EXPLANATION: A base of 12.9 GW.h (5% of lighting energy is assumed to be incandescent) and 50% of this is replaced with compact fluorescents with 75% reduction in electricity intensity.

BLOCK: C55
BUILDING TYPE: Secondary Schools
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 34
UNIT COST (¢/kW.h): 2.53
EXPLANATION: An investment of 12.92 ¢/ft^2 (annualized to 1.59 ¢/ft^2 over 10 years) yields savings of 0.63 kW.h/ft^2.

BLOCK: C56
BUILDING TYPE: Secondary Schools
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 6.5
UNIT COST (¢/kW.h): 1.12
EXPLANATION: An investment of 1.83 ¢/ft^2 (annualized to 0.135¢/ft^2 over 20 years) yields savings of 0.12 kW.h/ft^2.

BLOCK: C57
BUILDING TYPE: Secondary Schools
MEASURE: Motors Scheduling
SAVINGS (GW.h): 14.6
UNIT COST (¢/kW.h): 2.85
EXPLANATION: An investment of 6.25¢/ft^2 (annualized to 0.77¢/ft^2 over 10 years) yields savings of 0.27c/ft^2.

BLOCK: C58
BUILDING TYPE: Colleges/Universities
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 158
UNIT COST (¢/kW.h): 1.17
EXPLANATION: Lighting load assumed 95% fluorescent. Utilization assumed to be 3640 hours per year. Cooling credit of 10% of lighting savings assumed.

BLOCK: C59
BUILDING TYPE: Colleges/Universities
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 158
UNIT COST (¢/kW.h): 3.63
EXPLANATION: As for Block C58.

BLOCK: C60
BUILDING TYPE: Colleges/Universities
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 158
UNIT COST (¢/kW.h): 7.19
EXPLANATION: One photocell controller per eight fixtures. Total savings 75% relative to baseline. Annualized cost of electronic ballast and photocell controller at standard $6.62 per fixture.

BLOCK: C61
BUILDING TYPE: Colleges/Universities
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 11.4
UNIT COST (¢/kW.h): 3.0
EXPLANATION: Standard assumption that 75% savings can be achieved for 50% of the incandescent load by substituting compact fluorescents at $22/bulb. Total incandescent load before conservation measures at 5% of lighting energy.

BLOCK: C62
BUILDING TYPE: Colleges/Universities
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 45.3
UNIT COST (¢/kW.h): 2.53
EXPLANATION: Analysis as per secondary schools.

BLOCK: C63
BUILDING TYPE: Colleges/Universities
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 9
UNIT COST (¢/kW.h): 1.9
EXPLANATION: Analysis as per secondary schools.

BLOCK: C64
BUILDING TYPE: Colleges/Universities
MEASURE: Motors Scheduling
SAVINGS (GW.h): 19
UNIT COST (¢/kW.h): 2.85
EXPLANATION: Analysis as per secondary schools.

BLOCK: C65
BUILDING TYPE: Colleges/Universities
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 9
UNIT COST (¢/kW.h): 2.65
EXPLANATION: Savings of 18% are assumed (corresponding to prevalence of central cooling systems in this subsector). Pre lighting conservation savings potential of 16.4 GW.h at 1.8¢/kW.h is reduced by lighting measures to 14 GW.h at 2.07¢/kW.h for Level One, 11 GW.h at 2.35¢/kW.h for Level Two, and 9 GW.h at 2.65c/kW.h for Level Three.

BLOCK: C66
BUILDING TYPE: Hotels
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 15
UNIT COST (¢/kW.h): 0.77
EXPLANATION: Lighting load assumed 15% fluorescent, utilization factor 5750 hours per year. Cooling credit ignored.

BLOCK: C67
BUILDING TYPE: Hotels
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 15
UNIT COST (¢/kW.h): 2.57
EXPLANATION: As for Block C66.

BLOCK: C68
BUILDING TYPE: Hotels
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 12
UNIT COST (¢/kW.h): 6.2
EXPLANATION: Total savings 70% of baseline, reflecting limited potential for daylighting in this subsector. Photocells distributed one per eight fixtures.

BLOCK: C69
BUILDING TYPE: Hotels
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 129
UNIT COST (¢/kW.h): 3.0
EXPLANATION: Assume 50% of the incandescent bulbs are replaced with compact fluorescents. Initial lighting load is 85% incandescent. Cooling credit ignored.

BLOCK: C70
BUILDING TYPE: Hotels
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 56
UNIT COST (¢/kW.h): 1.39
EXPLANATION: An initial investment of 14¢/ft^2 (annualized to 1.72¢/ft^2 over 10 years) yields savings of 1.24 kW.h/ft^2.

BLOCK: C71
BUILDING TYPE: Hotels
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 20
UNIT COST (¢/kW.h): 0.58
EXPLANATION: An initial investment of 3.46¢/ft^2 (annualized to 0.58¢/ft^2 over 20 years) yields savings of 0.44 kW.h/ft^2.

BLOCK: C72
BUILDING TYPE: Hotels
MEASURE: Motors Scheduling
SAVINGS (GW.h): 89
UNIT COST (¢/kW.h): 3.08
EXPLANATION: An initial investment of 49.5¢/ft^2 (annualized to 6.10¢/ft^2 over 10 years) yields savings of 1.98 kW.h/ft^2.

BLOCK: C73
BUILDING TYPE: Hotels
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 19
UNIT COST (¢/kW.h): 1.8
EXPLANATION: It is assumed an average of 15% savings can be achieved for 1.8¢/kW.h in the base year cooling energy of 126 GW.h. The 15% figure reflects a mixture of the 12% and 18% savings achievable on unitary and central cooling equipment, respectively, which are both widely used in this subsector.

BLOCK: C74
BUILDING TYPE: Restaurants
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 97
UNIT COST (¢/kW.h): 0.9
EXPLANATION: Fluorescent lighting assumed to account for 50% of restaurant lighting. Utilization 5140 hours per year. Cooling credit ignored.

BLOCK: C75
BUILDING TYPE: Restaurants
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 97
UNIT COST (¢/kW.h): 3.1
EXPLANATION: As for Block C74. Cooling credit ignored.

BLOCK: C76
BUILDING TYPE: Restaurants
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 77
UNIT COST (¢/kW.h): 8.9
EXPLANATION: Total savings of 70% relative to the baseline. Four fixtures per photocell controller, extensive use of task lighting, cooling credit ignored.

BLOCK: C77
BUILDING TYPE: Restaurants
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 290
UNIT COST (¢/kW.h): 3.0
EXPLANATION: Assume 75% savings can be achieved in 50% of the incandescent fixtures by converting them to compact fluorescents.

BLOCK: C78
BUILDING TYPE: Restaurants
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 39
UNIT COST (¢/kW.h): 2.53
EXPLANATION: Analyzed as per secondary schools. 0.63 $kW.h/ft^2$.

BLOCK: C79
BUILDING TYPE: Restaurants
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 7
UNIT COST (¢/kW.h): 1.9
EXPLANATION: Savings of 0.12 $kW.h/ft^2$.

BLOCK: C80
BUILDING TYPE: Restaurants
MEASURE: Motors Scheduling
SAVINGS (GW.h): 17
UNIT COST (¢/kW.h): 2.85
EXPLANATION: Savings of 0.27 $kW.h/ft^2$.

BLOCK: C81
BUILDING TYPE: Restaurants
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 33
UNIT COST (¢/kW.h): 1.8
EXPLANATION: A 15% savings is assumed, representing a mix of the savings achievable with high efficiency unitary and central air cooling equipment.

BLOCK: C82
BUILDING TYPE: Hospitals
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 166
UNIT COST (¢/kW.h): 0.89
EXPLANATION: Utilization of 4500 hours per year, lighting load 95% fluorescent, 10% cooling credit.

BLOCK: C83
BUILDING TYPE: Hospitals
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 166
UNIT COST (¢/kW.h): 4.27
EXPLANATION: As for Block C82.

BLOCK: C84
BUILDING TYPE: Hospitals
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 166
UNIT COST (¢/kW.h): 8.22
EXPLANATION: Total savings of 75% relative to base-line, four fixtures per photocell controller.

BLOCK: C85
BUILDING TYPE: Hospitals
MEASURE: Compact Fluorescents
SAVINGS (GW.h): 12
UNIT COST (¢/kW.h): 3.0
EXPLANATION: Assumed savings of 75% for 50% of the incandescent lighting load.

BLOCK: C86
BUILDING TYPE: Hospitals
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 100
UNIT COST (¢/kW.h): 1.34
EXPLANATION: An initial investment of 14¢/ft^2 (annualized to 1.74¢/ft^2 over 10 years) yields savings of 1.3 kW.h/ft^2.

BLOCK: C87
BUILDING TYPE: Hospitals
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 14
UNIT COST (¢/kW.h): 0.71
EXPLANATION: An initial investment of 1.75¢/ft^2 (annualized to 1.29¢/ft^2 over 20 years) yields savings of 0.18 kW.h/ft^2.

BLOCK: C88
BUILDING TYPE: Hospitals
MEASURE: Motors Scheduling
SAVINGS (GW.h): 39.6
UNIT COST (¢/kW.h): 1.63
EXPLANATION: An initial investment of 7¢/ft^2 (annualized to 0.86¢/ft^2 over 10 years) yields savings of 0.53 KW.h/ft^2.

BLOCK: C89
BUILDING TYPE: Hospitals
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 19
UNIT COST (¢/kW.h): 2.3
EXPLANATION: Savings of 18% are assumed, corresponding to the prevalence of central cooling systems in this subsector. Assuming pre-lighting conservation potential at 1.8¢/kW.h, the potentials and unit cost premiums for efficient cooling equipment are 24 GW.h at 2.0¢/kW.h (Level One lighting), 22 Gw.h at 2.2¢/kW.h (Level Two lighting) and 10 GW.h at 2.3¢kW.h (Level Three lighting).

BLOCK: C90
BUILDING TYPE: Warehouse
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 145
UNIT COST (¢/kW.h): 1.55
EXPLANATION: Utilization 3000 hours per year.

BLOCK: C91
BUILDING TYPE: Warehouse
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 145
UNIT COST (¢/kW.h): 5.3
EXPLANATION: As for Block C90.

BLOCK: C92
BUILDING TYPE: Warehouse
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 145
UNIT COST (¢/kW.h): 9.6
EXPLANATION: Total savings 75% of baseline, eight fixtures per photocell controller, no cooling credit.

BLOCK: C93
BUILDING TYPE: Warehouse
MEASURE: Motors -- Balancing
SAVINGS (GW.h): 151
UNIT COST (¢/kW.h): 1.6
EXPLANATION:

BLOCK: C94
BUILDING TYPE: Warehouse
MEASURE: Energy Efficient Motors
SAVINGS (GW.h): 29
UNIT COST (¢/kW.h): 1.9
EXPLANATION:

BLOCK: C95
BUILDING TYPE: Warehouse
MEASURE: Motors Scheduling
SAVINGS (GW.h): 65
UNIT COST (¢/kW.h): 2.9
EXPLANATION:

BLOCK: C96
BUILDING TYPE: Warehouse
MEASURE: High Efficiency Cooling Equipment
SAVINGS (GW.h): 21
UNIT COST (¢/kW.h): 1.8
EXPLANATION: Savings of 12% are assumed, corresponding to the savings for unitary cooling equipment.

BLOCK: C97
BUILDING TYPE: Recreation
MEASURE: Fluorescent Lighting -- Level One
SAVINGS (GW.h): 20
UNIT COST (¢/kW.h): 0.9
EXPLANATION: Utilization 5000 hours per year, no cooling credit.

BLOCK: C98
BUILDING TYPE: Recreation
MEASURE: Fluorescent Lighting -- Level Two
SAVINGS (GW.h): 20
UNIT COST (¢/kW.h): 3.2
EXPLANATION: As for Block C97.

BLOCK: C99
BUILDING TYPE: Recreation
MEASURE: Fluorescent Lighting -- Level Three
SAVINGS (GW.h): 20
UNIT COST (¢/kW.h): 5.76
EXPLANATION: Eight fixtures per photocell controller, overall savings of 75% relative to baseline.

BLOCK: C100
BUILDING TYPE: Recreation
MEASURE: Motors
SAVINGS (GW.h): 145
UNIT COST (¢/kW.h): 2.0
EXPLANATION: In the absence of any detailed analysis of this sector, which is actually quite diverse in composition, we have simply assumed that a 25% savings in motor electricity could be achieved for less than 2¢/k/W.h, consistent with findings in other subsectors.

BLOCK: C101
BUILDING TYPE: Other
MEASURE: Lighting
SAVINGS (GW.h): 250
UNIT COST (¢/kW.h): 4.53
EXPLANATION: In the absence of detailed knowledge of this sector, a savings potential of 50% for lighting has been assumed to be available at costs less than 4.5¢/kW.h.

BLOCK: C102
BUILDING TYPE: Other
MEASURE: Motors
SAVINGS (GW.h): 160 GW.h
UNIT COST (¢/kW.h): 2.0
EXPLANATION: Savings of 20% assumed for combination of motor measures at less than 2.0¢/kW.h.

BLOCK: C103
BUILDING TYPE: Other
MEASURE: Cooling
SAVINGS (GW.h): 35
UNIT COST (¢/kW.h): 2.0
EXPLANATION: Savings of 10% assumed for high efficiency cooling equipment.

BLOCK: C104
BUILDING TYPE: All
MEASURE: Water Heating
SAVINGS (GW.h): 161.6
UNIT COST (¢/kW.h): 2.0
EXPLANATION: As described in Section A.2.8, a savings of 20% is assumed achievable at less than 2.0¢/kW.h.

BLOCK: C105
BUILDING TYPE: All
MEASURE: Space Heating, General
SAVINGS (GW.h.): 430
UNIT COST (¢/kW.h): 2.5
EXPLANATION: There is a considerable amount of electric space heat in the commerical/instituional sector (we estimate 4300 GW.h in 1985) and yet it is often ignored in calculations of commerical sector conservation potential. In the absence of detailed studies, we have made the conservative assumption that a modest 10% savings could be achieved for 2.5¢/kW.h.

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APPENDIX B -- INDUSTRIAL SECTOR CALCULATIONS

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B.1 Base Year Electricity Use

Ontario Hydro figures indicate 153 PJ of electricity were purchased by industry in 1985, the base year for this study. This is equivalent to 42,400 GW.h. On a broad average, 15% of this electricity is used for process applications; the other 85% is used by motors, lighting, refrigeration, space conditioning, etc. Based on data for specific industries [Ontario Hydro 1986c], the distribution is taken as follows:

75% motors
8% lighting
2% refrigeration

B.2 Calculation of Supply Curve Components

BLOCK: I0
MEASURE: INSULATION AND HOUSEKEEPING MEASURES
SAVINGS: Indeterminate
UNIT COST: Low cost/no cost
EXPLANATION: Almost since the start of attention to industrial energy conservation, it has been argued that a variety of no-cost/low-cost measures that focus mainly on insulation, valve tightening and simple housekeeping (closing doors, turning off unneeded lights, etc.) could save from 15 to 25% of the energy used in typical plants. Visits by the Energy Bus Program of the federal and provincial governments generally justified such statements, at least for energy-non-intensive firms. Project assessments have shown specific savings of 1 to 3% from each step in insulation at costs of around 0.1¢/kW.h.

Unfortunately, it is not clear how much of the one-time saving from insulation and housekeeping has already been attained, nor the proportion of firms that have adopted the required measures. Therefore, while it is reasonable to assume that some additional savings remain to be obtained, and further that some of those savings will involve electricity, no specified block of available savings can be determined for these measures.

BLOCK: I1
MEASURE: WASTE HEAT RECOVERY
SAVINGS (GW.h): 1900
UNIT COST (¢/kW.h): 0.3
EXPLANATION: Earlier studies have shown that there is a large potential for waste heat recovery in process industries [Diener and James 1981, James 1982]. Based on a sample of industrial conservation projects, it was concluded that some 4.5% of total industrial energy use in Canada could be saved at an average cost of $0.839/GJ (1981$, 10% discount rate); if weighted by savings, costs fall to $0.417/GJ. As would be expected, the cost range for heat recovery projects generally fall between those for insulation/housekeeping and those for process change. Exactly the same is true in developing countries [Anandalingam 1985].

If one assumes that what is true for Canada is true for Ontario, and also that waste heat recovery potential is evenly distributed across fuels, then, one can say that 4.5% of electrical energy used in Ontario industry could be saved through waste heat recovery at costs below those cited above (equivalent to 0.15 or 0.3¢/kW.h), depending on the choice of average. Given that all this will be obtained from process applications (15% of industrial electricity use), 30% of process electricity could be saved. The equation of potential savings is therefore:

42,400 GW.h X 0.15 X0.30 = 1900 GW.h

BLOCK: I2
MEASURE: PROCESS CONTROLS AND INSTRUMENTATION
SAVINGS (GW.h): 400
UNIT COST (¢/kW.h): 0.15
EXPLANATION: A study of industrial energy use in Canada investigated several projects in which improved process controls and instrumentation were used to save energy. Overall savings of about 1% were achieved for costs of $0.44/GJ. These costs are so low that it seems reasonable to assume that approximately the same degree of saving could be achieved in electricity alone. If so, the saving would amount to 400 GW.h at a cost of 0.15c/kW.h.

BLOCK: I3
MEASURE: LIGHTING
SAVINGS (GW.h): 1700
UNIT COST (¢/kW.h): 3.5
EXPLANATION: As indicated above, lighting accounts for 8% of industrial electricity use. The analysis for the commercial sector shows that 25 to 50% savings are readily

attainable from improved tubes, ballasts and fixtures for annualized unit costs between 0.8 and 5.0¢/kW.h. Assuming the equivalent of Level Two measures (see commercial sector analysis), we have included 50% savings in lighting energy use at an average unit cost of 3.5¢/kW.h. Total savings amount to 42,400 GW.h * 0.08 * 0.5 = 1700 GW.h.

BLOCK: I4
MEASURE: REFRIGERATION
SAVINGS (GW.h): 200
UNIT COST (¢/kW.h): 1.9¢/kW.h
EXPLANATION: As indicated above, refrigeration accounts for about 2% of industrial electricity use. Ontario Hydro estimates savings are possible for 1.9¢/kW.h (mid-point of range) [Ontario Hydro 1986c]. In other studies, it has been shown that existing technology offers a cost-effective potential to cut energy use in ordinary household refrigerators and freezers by a factor of two. While by no means all of this potential would apply to industrial refrigeration, some part of it would. In the absence of specific information, 25% savings are assumed possible. The savings equation therefore is

42,400 GW.h * 0.02 * 0.25 = 200 GW.h

BLOCK: I5
MEASURE: MOTORS
SAVINGS (GW.h): 715
UNIT COST (¢/kW.h): 1.0
EXPLANATION: If the number of motors in each size range is compared with energy use by motors in each size range, the two distributions will appear to be almost mirror images of one another. The bulk of motors are small -- more than 90% under 1 HP (3/4 kW) -- but the bulk of energy use is accounted for by the large industrial motors. Close to half the electricity use is accounted for by motors larger than 125 HP (93kW). The distinction is critical because small motors are quite inefficient, but larger ones are not. Therefore it becomes critical to know the distribution of motors in industry by size.

Several studies have looked at the distribution of energy use by motors of different size in industry. A U.S. Dept. of Energy study [USDOE 1980] based on 1977 data showed the following:

HP Range	% of Motors	% of Electricity
5.1 - 20	62	8.1
21 - 50	22	12.1
51 - 125	8	26.5
>125	4	6.9

In some industrial subsectors, the weighting toward large motors is even greater. Some 70% of the electricity taken by motors in a large kraft pulp and paper mill may be accounted for by units larger than 125 HP. Ignoring some special types of motors altogether, the distribution of energy use by industrial motors is roughly 13% small motors, 12% medium motors and 75% large motors.

B.C. Hydro made a study of the efficiency gains that could be expected in motors of different sizes [Henriques and Ilic 1980]. This work conforms closely to that of other analyses and suggests that improvements are now possible as follows:

Motors less than 5 HP:	4.0% gains
Motors between 5 and 50 HP	2.5% gains
Motors larger than 125 HP	1.9% gains.

Lovins [1985] argues that much larger gains are possible, even for large motors, once the whole drive train is taken into account. For example, in one analysis he found 11 ways to improve efficiencies in a groundwood pulp and paper mill, which, together, offered savings of 15 to 30% in electrical use at costs well under those for conventional power.

To be conservative, the analysis presented here is restricted to improved motor efficiency itself and the potential for better instrumentation (Block I2) and variable speed motors (Block 6). These various pieces of information can be combined to produce an equation for savings as follows:

$$42{,}400\ \text{GW.h} * 0.75\ (0.13 * 0.04 + 0.12 * 0.025$$

$$+ 0.75 * 0.019 = 715\ \text{GW.h}$$

The premium cost of energy efficiency motors has been shown in the commercial sector analysis (Appendix A) to be consistently less than 1.0¢/kW.h, and this is used as a conservative estimated for the savings included in this block.

BLOCK: I6
MEASURE: VARIABLE SPEED MOTORS
SAVINGS (GW.h): 960
UNIT COST (¢/kW.h): 3
EXPLANATION: Information of variable speed motors is still developing, but there is now enough experience to offer tentative generalizations as to potential [Birkett 1987, Sharpe 1987]. It appears that the main gains will lie in economizing on energy use, not (or at least not necessarily) on peak loads. While costs and savings will vary even more widely among firms than with other measures, estimates of overall potential suggest that savings of around 960 GW.h in Ontario are feasible for costs of 2 to 4¢/kW.h.

APPENDIX C -- RESIDENTIAL SECTOR CALCULATIONS

APPENDIX C -- RESIDENTIAL SECTOR CALCULATIONS

C.1 Base Year Electricity Use

In 1985, Ontario's population of $9.06 * 10^6$ was comprised of $3.246 * 10^6$ households, of which $1.865 * 10^6$ occupied single family detached dwellings, $.40 * 10^6$ occupied single family attached dwellings (row, duplex, semi), and the remaining $0.982 * 10^6$ occupied apartment units.

Total electricity use in 1985 was approximately 131.5 PJ or 36,600 GW.h, broken out by major end use as follows:

Appliances	19,500 GW.h
Space heating	9,200 GW.h
Water heating	7,300 GW.h
Space cooling	600 GW.h

Data from Ontario Hydro for electricity use per appliance combined with saturation rates for the appliances yield the following estimated disaggregation of the appliance electricity use:

Appliance	Average Use (kW.h/yr)	Saturation	GW.h
Fridge	1200	1.28	5000
Freezer	900	.63	1850
Lighting	800	1.00	2600
Range	950	.90	2800
Clothes Dryer	1000	.64	2100
Furnace Fans	400	.61	800
Other			4350

Where water heating is provided by electricity, the estimated average electricity use per household is 5300 kW.h/year, with 1985 saturation estimated to be about 42% of Ontario households.

Supplementary space heating with electricity is not considered is this study. The electricity use for space heating shown above is estimated to break down as follows:

250,000 Pre-1981 Single Family Detached (SFD) Average 85 GJ or 23,630 kW.h	5900 GW.h
50,000 1981-1985 SFD's at 60 GJ or 16,680 kW.h	835 GW.h
44,000 pre-1981 Semi-Duplex at 52 GJ or 14,500 kW.h	638 GW.h
10,000 1981-1985 Semi-Duplex at 36 GJ or 10,000 kW.h	100 GW.h
23,000 pre-1981 row units at 35 GJ or 9730 kW.h	225 GW.h
15,000 1981-1985 row units at 24 GJ or 6672 kW.h	100 GW.h
120,000 pre-1981 Apartments at 30 GJ or 8340 kW.h	1000 GW.h
40,000 1981-1985 Apartments at 20 GJ or 5560 kW.h	220 GW.h

These estimates of the base year electricity consumption are used as the basis for calculating conservation potential.

C.2 Calculation of Supply Curve Components

BLOCK: R1
MEASURE: ENERGY EFFICIENT REFRIGERATORS
SAVINGS (GW.h): 3095
UNIT COST (¢/kW.h): 2.04
EXPLANATION: The technical potential for efficiency improvements in refrigerators is enormous; designs still at the developmental stage may yield as much as 80% savings in electricity use. The Whirlpool ET17HKIM uses only 750 kW.h per year compared to our standard. While it has a small premium relative to other Whirlpool models, it is comparable in price to other brands of the same capacity and features. The California standard for 1992 is about 610 kW.h, or about half the average Ontario fridge in 1985, and the premium costs for this saving has been conservatively estimated by Geller at $81, or 1.13¢/kW.h annualized over a 17 year lifetime [ACEEE, 1986] (we have converted to Canadian

dollars). The same study for Pacific Gas and Electric estimates a $185 premium (2.04¢/kW.h annualized) for a relatively "low technology" fridge that uses only 460 kW.h per year. The most advanced available technology could result in fridges comparable to our base year fridge that would use only 175 kW.h/year, for a $425 premium (3.4¢/kW.h annualized). This technical potential would result in savings of 4288 GW.h in our base year consumption for refrigerators. To be conservative, we have assumed the low technology level of improvement, yielding 3095 GW.h at 2.04¢/kW.h.

BLOCK:	R2
MEASURE:	ENERGY EFFICIENT FREEZERS
SAVINGS (GW.h)	1164
UNIT COST (¢/kW.h(:	2.58

EXPLANATION: The efficiency of freezers has been dropping since the mid-1970's. We have assumed an average use in 1985 of 900 kW.h (Ontario Hydro). This is typical of the models on the market in 1985, but seems low as an average for the stock. Before manufacturers began improving the efficiency of freezers in the 1970's, typical models consumed nearly 2000 kW.h/year [ACEEE, 1986]. According to Geller [ACEEE 1986], a $100 premium (2.45¢/kW.h annualized) brings consumption down to 600 kW.h per unit (from 900 kW.h) and electricity use of about 330 kW.h/unit can be easily achieved for a $200 premium (2.58¢/kW.h annualized over 20 years).

BLOCK:	R3
MEASURE:	LIGHTING
SAVINGS (GW.h):	792
UNIT COST (¢/kW.h):	6.2

EXPLANATION: While there are several dozen light bulbs in a typical household, there are usually a small number that are used for extended periods every day. This is an important distinction because the cost effectiveness of advanced lighting technologies is directly proportional to the utilization factor. We have assumed that the typical household has four 60W incandescent bulbs that are on for at least four hours a day and that these are replaced by 18W compact fluorescents at a cost of $20 each and with an assumed lifetime of 9000 hours. Without taking credit for the cost of the incandescent bulbs replaced by the compact fluorescent, the annualized cost of $3.80 per bulb yields savings of 61 kW.h per year for a unit cost of 6.2¢/kW.h. The total potential savings are 244 kW.h per household or 792 GW.h for the sector.

BLOCK: R4
MEASURE: ATTIC INSULATION
HOUSING TYPE: PRE-1981 SFD
SAVINGS (GW.h): 590
UNIT COST (¢/kW.h): 2.28
EXPLANATION: Ontario Hydro [1986a] provides estimates of the cost of upgrading attic insulation to R50 from a range of starting points. We have assumed 10% savings can be achieved by upgrading from R20 to R50 in the pre-1981 SFD stock at a per unit cost of $931 and a useful lifetime of 30 years.

BLOCK: R5
MEASURE: INFILTRATION IMPROVEMENTS
HOUSING TYPE: PRE-1981 SFD
SAVINGS (GW.h): 885
UNIT COST (¢/kw.h): 1.6
EXPLANATION: Adopting Ontario Hydro's [1986a] infiltration package, 15% savings (independent of the attic insulation) can be achieved with a per unit investment of $980. With a 30 year useful lifetime, the annualized cost of $56.64 saves 3545 kW.h per year for a unit cost of 1.6¢/kW.h and a total potential of 885 GW.h.

BLOCK: R6
MEASURE: DOOR IMPROVEMENTS
HOUSING TYPE: PRE-1981 SFD
SAVINGS (GW.h): 295
UNIT COST (¢/kW.h): 3.42
EXPLANATION: Once again adopting the Ontario Hydro figures for costs, doors are improved from R2 to R15 at an average unit cost of $700 and a savings of 5% of the base consumption. Using a useful life of 30 years, the annualized cost of the door improvements is $40.46, yielding a unit cost of 3.42¢/kW.h. Total savings potential is 295 GW.h.

BLOCK: R7
MEASURE: BASEMENT INSULATION
HOUSING TYPE: PRE-1981 SFD
SAVINGS (GW.h): 413
UNIT COST (¢/kW.h): 1.75
EXPLANATION: We have assumed additional 7% savings (relative to the baseline) can be achieved through a $500 per unit investment in basement insulation. The annualized cost of $28.90 (30 years) saves 1654 kW.h for a unit cost of 1.75¢kW.h. Total potential is 413 GW.h.

BLOCK: R8
MEASURE: WINDOW UPGRADES
HOUSING TYPE: PRE-1981 SFD
SAVINGS (GW.h): 590
UNIT COST (¢/kW.h): 9.3
EXPLANATION: We have assumed $3000 in some window upgrading or replacement would yield a 10% saving relative to the baseline consumption. The annualized cost of $220.74 (20 years) saves 2363 kW.h for a unit cost of 9.3¢/kW.h. The total potential is 590 GW.h.

BLOCK: R9
MEASURE: ATTIC INSULATION
HOUSING TYPE: 1981-1985 SFD
SAVINGS (GW.h): 44.5
UNIT COST (¢/kW.h): 4.4
EXPLANATION: Newer SFD stock is assumed to have attic insulation levels of R28 which is upgraded to R50 at a cost of $683 and savings of 890 kW.h per year. The annualized cost of $39.47 (30 years) yields a unit cost of 4.4¢/kW.h, and a total potential of 44.5 GW.h.

BLOCK: R10
MEASURE: INFILTRATION IMPROVEMENTS
HOUSING TYPE: 1981-1985 SFD
SAVINGS (GW.h): 115
UNIT COST (¢/kW.h): 2.46
EXPLANATION: The cost per household is the same ($980) as for the newer SFD's but the savings are smaller due to the higher base levels of efficiency in this stock. The annualized cost of $56.64 saves 2300 kW.h in this stock, for a unit cost of 2.46¢/kW.h and a total potential of 115 GJ.

BLOCK: R11
MEASURE: DOOR IMPROVEMENTS
HOUSING TYPE: 1981-1985 SFD
SAVINGS (GW.h): 32
UNIT COST (¢/kW.h): 6.32
EXPLANATION: The same investment ($700) as for the older stock yields per household savings of 640 kW.h for a unit cost of 6.32¢/kW.h and a total potential of 32 GW.h.

BLOCK: R12
MEASURE: INFILTRATION MEASURES
HOUSING TYPE: PRE-1981 ELECTRIC HEATED APARTMENTS
SAVINGS (GW.h): 150
UNIT COST (¢/kW.h): 0.59

EXPLANATION: Estimates by EIL for Ontario Hydro [1986b] indicate investments of 10¢/ft^2 in infiltration improvements will yield savings of 0.62 kW.h/ft^2 in large all-electric apartment buildings. Scanada [1979] estimates much larger savings are possible for about double the costs suggested by EIL in the study for Ontario Hydro. We have assumed that an investment of $100/unit (about 10¢/ft^2) will yield savings of 15% in this older stock. The annualized (20 years) unit cost per apartment of $7.36 yields savings of 1251 kW.h for a unit cost of 0.59¢/kW.h and a total potential of 150 GW.h.

BLOCK: R13
MEASURE: WATER HEATING IMPROVEMENTS
HOUSING TYPE: ALL TYPES
SAVINGS (GW.h): 2530
UNIT COST (¢/kW.h): 0.79
EXPLANATION: There is a great deal of wasted electricity in the heating of water that could be saved with very little direct cost. The inaccessibility of the thermostats and the tendency for the heaters to be set at high (even dangerously high) temperatures on installation is one example where essentially no-cost savings are available. The latest designs of water using appliances such as dishwashers and clothes washers use less water and require it at lower temperatures than the models of a few years ago.
Flow restrictors (while arguably a "lifestyle" measure, can also significantly reduce consumption. Education campaigns for the conservation and efficiently use of water in general will also save electricity, and these campaigns can be expected to increase with the cost and difficulty of maintaining municipal water supplies. We assume that per capita water use continues to drop to 290 L/week (a level already reached in parts of Canada [Monenco 1983]) and that an average temperature of 55^{o}C above ambient becomes the norm. These two measures alone would cut use by 35%. To be conservative we have assumed a per household cost of $200 to achieve a 35% savings. Annualized over 20 years, the unit cost is 0.79¢/kW.h and the total potential is 2530 GW.h, relative to 1985 consumption levels.

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